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# RESEARCH JOURNAL





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# Avenues to Improve Farm Income from Cotton under Changing Climatic Scenario

**M. V. Venugopalan**

## ABSTARCT

During the last decade (2007-08 to 2017-18) cotton yields have plateaued in the country and remained between 500 and 550 kg lint $ha^{-1}$, despite near saturation with BG II Bt hybrids. Technology fatigue, climate change, emergence of new pests and diseases, resistance to cry toxins in pink bollworms are some reasons attributed to this scenario. Profit of cotton farmers can be increased through improving cotton yields, reducing production costs and/or increasing the output prices. This paper analysed the impact of climate scenarios on future cotton productivity, cause for low productivity of rainfed cotton and discusses the best management practices (BMPs), validated through research conducted at ICAR-CICR and AICRP on Cotton for improving cotton yield and farm income. Simulation studies indicated that under rainfed conditions, compared to the base-line scenario, adoption of improved BMPs have a potential to increase the rainfed cotton yields by 22.8 per cent and 21.7 per cent in the projected (MIROC HI 3.2 A1b and B1, PRECIS A1b, A2, B2) 2050 and 2080 climatic scenarios, respectively. Low yield of rainfed cotton is mainly due to the mismatch of the monsoon window with the late season flowering and fruiting stages that in turn starve the cotton plant of water and nutrients besides aggravating the loss due to Pink Boll Worm (*Pectinophora gossypiella*). Our studies conducted on research farms as well as farmers field helped us to conclude that short duration, early maturing Bt *G. hirsutum* varieties and long linted *G. arboreum* varieties with high harvest-index and heat tolerance, timely plantingusing High Density Planting Systems (HDPS), conservation tillage and crop residue management practices and synchronized nutrient delivery systems can be helpful in adapting to climatic uncertainties, improve cotton yields, increase input use efficiency and reduce production costs. Based on these findings a road map for improving farm income is also discussed.

The honourable Prime Minister's Shri Narendra Modi's call for doubling the income of farmers by 2022 was formalized in the Union Budget 2016-17. Since then several scholars expressed their views, possibilities and reservations about its feasibility. Chand (2017) Member, NITI Ayog suggested a three pronged strategy focussing primarily on development initiatives, technological breakthroughs and policy reforms. Under technological breakthroughs, he suggested agronomic opportunities to improve resource use efficiency. The income of cotton farmers can be increased through technological innovations aimed at improving cotton yields per unit of inputs added, reducing production costs and/or increasing the output prices. However, under the current national cotton scenario, low cotton yields, limited opportunity for diversification and wide year to year fluctuation are serious obstacles in doubling the income of rainfed cotton farmers.

Figure 1 depicted the cotton scenario in India during the last 17 years. After the introduction of Bt

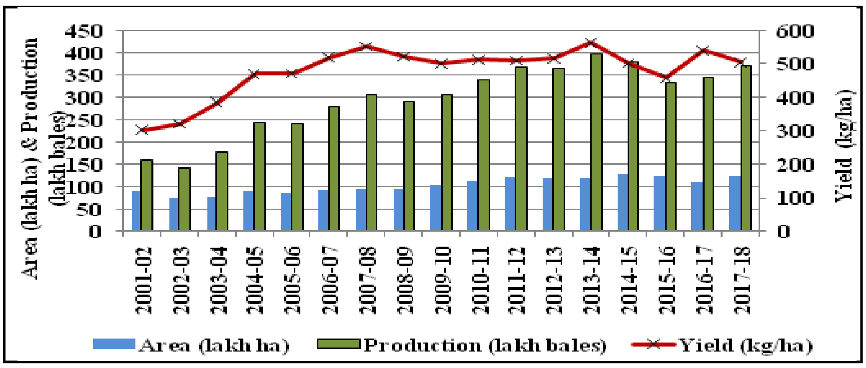


**Figure 1: Trends in Area, Production & Productivity of Cotton in India**

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hybrids in 2002-03, the productivity of cotton steadily increased till 2007-08 and plateaued thereafter and remained between 500 and 550 kg lint $ha^{-1}$, despite near saturation with BG II Bt hybrids. It is pertinent to note that during 2017-18; only 68 per cent of the 94.13 lakh hectares area was under Bt hybrids (Singh, 2017). The highest yield of 568 kg $ha^{-1}$ was during 2007-08 and in the subsequent years, yields have declined despite progressive increase in area under Bt hybrids, release of new Bt hybrids, the introduction of the Bollgard II, approval of new Bt events, increased use of fertilizes and insecticides (Venugopalan *et al.,* 2018). Analysis of the yield data also indicates a high coefficient of variation in cotton productivity to the tune of 15.7 per cent, a sign of instability in productivity. The weighted average cost of production using actual prices increased from Rs 1846 $q^{-1}$ in 2007-08 to Rs 4803 $q^{-1}$ in 2015-16 with huge variation across states (Reddy *et al.,* 2016). Today, labour cost alone account to nearly 50 per cent of the production cost of cotton.

Global warming induced inter-annual monsoon rainfall variability in India is one of the reasons for high degree of temporal variation in cotton yields. Climate change projections for India indicate an overall increase in temperature by 1 to $4^0$C and precipitation by 9-16 per cent towards 2050s with an increase in the frequency of occurrence of extreme events such as droughts, floods and cyclones (Krishna Kumar *et al.*, 2011). These changes are likely to have an impact on cotton productivity further jeopardizing the goal of doubling farm income. It is recognized widely that both that adaptation and mitigation strategies are equally important in dealing with climate change (Rama Rao *et al.,* 2013). About 60 per cent of the cotton is rainfed. In this context, the objectives of this study was to understand the impact of climate change on under future climatic scenarios on cotton productivity, simulate the effect of adaptation strategies on cotton under future climatic scenarios and validate simple management techniques to improve cotton yields and income of farmers.

## MATERIAL AND METHODS

This paper analysed the impact of climate scenarios on future cotton productivity, cause for low productivity of rainfed cotton and discusses the best adaptation strategies developed and validated through research conducted at ICAR-CICR and AICRP on Cotton for dealing with climatic uncertainties and improving the income of cotton farmers.

The inferences are drawn from the following research projects conducted at ICAR-Central Institute for Cotton Research, Nagpur

* Climate change- adaptation and mitigation strategies in cotton (under National Initiative on Climate Resilient Agriculture).
* Evaluation of genotypes and standardization of agro-techniques for high density planting and surgical cotton production (Technology Mission on Cotton)
* Exploring the productivity potential of long-linted *G. arboreum* cotton.
* Development of Bt cotton varieties using deregulated and non deregulated transgenic events and from the outcome of workshops conducted at ICAR-CICR on prioritizing the research agenda for cotton.

Using Info Crop, a generic crop growth process based dynamic simulation model, we assessed the impact of climate change on cotton productivity and the adaptation opportunities in the different cotton growing states of India. For simulating yields in future scenarios, temperature (minimum and maximum) and rainfall data from MIRO HR -A1b, B1 for 2050 and 2080 scenarios; the PRECIS A1b, A2 and B2 for 2080 scenarios were used for analysis. 'Delta method' - used to overcome variation between observed weather and climate model outputs for baseline period (Naresh Kumar *et al.*, 2014).

Gridded daily data $1^o$ x$1^o$ on rainfall and temperatures (IMD Pune-22 years (1969-1990) and solar radiation calculated by Hargreaves method, best suited for Indian conditions (Bandyopadhyay *et al.,* 2008) was used for simulation. Soil data generated by the National Bureau of Soil Science and Land Use Planning, Nagpur and Harmonized Global Soil Profile Dataset (Batjes, 2008) were used and appropriate PTFs were employed to obtain the soil hydraulic characteristic coefficients. Varietal coefficients were developed for medium and short duration cotton hybrids through field studies. Analysis for irrigated–timely sown or rainfed monsoon season (C and S zone and summer sown irrigated N zone) was done assuming recommended package of practices. In view of limited understanding on the crop-pest interaction in future climates, it was assumed that crop was maintained free of pest and diseases.

For the estimation of baseline yield, seed cotton yield of all the 22 years (1969-1990), were simulated. District-wise baseline yield was obtained as sum of the weighted yield from each grid fraction in district. The simulated yield output was calibrated to district yield (district mean yield of 2000-2005 period ; DES, 2012) to get 'baseline yields calibrated to 2000-05 period'.

For simulating the impact of adaptation strategies, several low cost and easy-to-adopt options were tested independently or in combination for 2020, 2050 and 2080 scenarios under rainfed condition. These include, timely sowing, switch over to short duration compact (150 days) cotton varieties, high planting density, split application of N, life saving irrigation and integrated N management. Combination which gave highest yield in each grid was taken as best suitable adaptation option. The net change in mean yield of all 22 years was expressed as relative difference from mean baseline yield. For evaluation and validation of improved agro-techniques, field experiments were conducted and data was analysed using standard statistical procedures (Gomez and Gomez,1984)

## RESULTS AND DISCUSSION

**Impact of projected climate scenarios on future cotton productivity**

The simulated net impact of future climatic scenarios, on mean seed cotton yields, expressed as a percentage of baseline yield is presented and discussed.

**Table 1: Impact of projected future climate scenarios on the simulated productivity of irrigated cotton in North India and rianfed cotton in Central and South India (per cent change over baseline yield)**

| States | Mean 2050 | Mean 2080 |
|---|---|---|
| Punjab (I) | -19.79 | -22.01 |
| Haryana (I) | -16.39 | -18.42 |
| Rajasthan (I) | -25.05 | -26.05 |
| Gujarat (R) | 3.49 | 2.08 |
| Madhya Pradesh (R) | 12.01 | 12.30 |
| Maharashtra (R) | 8.09 | 4.10 |
| Andhra Pradesh (R) | 14.20 | 4.33 |
| Karnataka (R) | 6.80 | 9.30 |
| Tamil Nadu (R) | 16.06 | 19.33 |

The results presented in Table 1 indicated that under irrigated conditions, over baseline yield the simulated seed cotton yields are likely to decline in all the three states of North Zone under 2050 and 2080 scenarios. The magnitude of yield reduction would be highest in Rajasthan. The impact of climate change scenarios in the rainfed cotton growing regions indicated a moderate increase in the productivity under 2050 and 2080 scenarios. The mean productivity would increase by 6.4 per cent and 5.1 per cent per cent from the baseline yields by 2050 and 2080, respectively. The magnitude of gain is likely to be lower in Andhra Pradesh, Maharashtra and Gujarat. Earlier Hebbar *et al*. (2013) concluded that the impact of

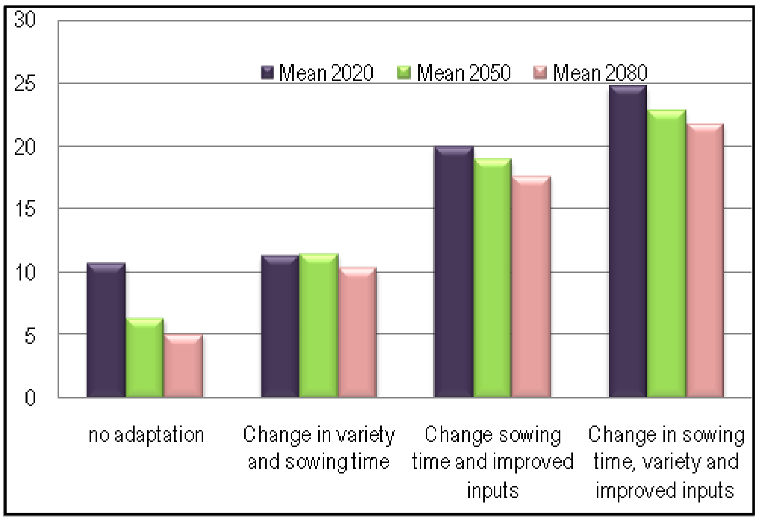


**Fig. 2: Quantification of adaptation gains (per cent) due to technological interventions in rainfed cotton**

climate change on Indian cotton was likely to be minimal on account of increase in rainfall in rainfed areas of central and south zone would compensate the likely decline in yield in the north zone due to high temperature.

**Impact of adaptation strategies on seed cotton yields under projected future climatic scenarios**

Adaptation strategies in the short term are aimed at minimizing the negative impacts and capitalize on the new opportunities provided by future climatic situations.

Results depicted in figure 2 indicated that under rainfed conditions, compared to the present no adaption scenario, improved management strategies *viz.* short duration, compact varieties and early sowing dates and improved water and N management have a potential to increase the rainfed cotton yields by 24.3, 22.8 per cent and 21.7 per cent in the 2020, 2050 and 2080 scenarios, respectively.

**Challenges for cotton research and development**

Venugopalan *et al.* (2016) enumerated the following challenges confronting the contemporary Indian cotton production system

1. Genetic erosion and narrowing of genetic diversity in the cultivated varieties and hybrids makes the crop vulnerable to biotic and abiotic stresses and absence of public sector varieties with broader genetic base
2. Resistance development in pink boll worm to Cry I AC and Cry 2 Ab toxins present in Bt cotton
3. Low productivity levels (around 500-550 kg lint ha$^{-1}$).
4. Rising production costs and declining profit margin.
5. Poor fibre quality in terms of strength and micronaire. Decline in ELS cotton production
6. Decline in partial factor productivity of inputs particularly fertilizers.
7. Low soil organic carbon content of cotton growing soils and non availability of organic manures in sufficient quality and non-adoption of soil regenerating cropping systems.
8. Imbalanced fertilizer use (more N) and micro nutrient deficiencies resulting in increased insect pests, insect resistance to insecticides and concomitant increased insecticide use.
9. Non availability of irrigation facilities even to provide protective, life saving irrigation in 60 per cent of the planted area.
10. Climate change, erratic monsoon and aberrant distribution of rainfall.
11. Non availability of low cost machines (sowing, picking) for adoption by small farmers. Labour shortage and enhanced wages.

**Reasons for low yields in India**

Kranthi (2017) listed these few unique features of Indian cotton responsible for low yields.

**1. Fascination for more bolls plant$^{-1}$ :** Ever since hybrid cotton was introduced in 1970s, cotton breeders in India have developing bushy hybrids and also varieties that produce the highest number of bolls plant$^{-1}$. In this process the duration of fruiting period and in turn, the duration of the variety increased. However, globally cotton breeders developed compact varieties with only 10-15 bolls plant$^{-1}$. It is difficult to get more number of bolls plant$^{-1}$ particularly under marginal growing conditions resulting in poor yields.

**2. High input oriented technologies:** Hybrids are developed under ideal conditions and are later grown in sub-optimal growing conditions. The yield potential of hybrids can be exploited only with 'high input intensive' practices that are beyond the reach of majority of the farmers. Hence, the true potential of hybrids is seldom realized.

**3. Long duration of cultivars and moisture stress:** Majority of hybrids are long duration (200-220 days). They encounter moisture stress during the peak boll formation stage in rain-fed regions. In the absence of protective/supplemental irrigation, fewer bolls are set and the bolls forming late, open before maturing fully giving low yield with immature fibres.

**4. Need for more pesticides and use for mixtures:** Because of the longer duration and susceptibility to sucking pests, majority of the hybrids need more pesticides for protection against pests and diseases. Most of the hybrids are highly susceptible to sap sucking insects. Wrong choice of molecules and their combinations lead to disruption of the naturally occurring bio-eco-systems and thus necessitate the need for more and more insecticides.

**5. Leaf reddening, para-wilt and leaf curl virus:** Owing to a combination of biotic and abiotic reasons, cotton crop succumbs to leaf reddening and parawilt. Hasty release of Bt hybrids without proper screening has also aggravated the menace of leaf curl virus

**6. Late sowing:** Hybrids are sown only when soil moisture is adequate for proper germination. Late sowing even by 7-10 days leads to 20-30 per cent reduction in yields.

**7. High cost of cultivation and decline in factor productivity:** Hybrid seed production is highly labour intensive, cumbersome and expensive making the seeds expensive. Due to wider spacing, hybrids need continuous inter-culture and weeding upto 90 days. The nominal cost of cultivation (at current prices) increased @ 9.5 per cent per annum during triennium ending 2001-02 to triennium ending 2009-10. In absolute terms, the increase was from Rs 16037 $ha^{-1}$ to Rs 35275 $ha^{-1}$ during the same period (Suresh *et al*., 2013) and there has been a reduction in partial factor productivity of fertilizers

**Thrust areas to increase cotton yield and profits from cotton cultivation:**

From the list of Global Best Management Practices, during the last few years, ICAR-CICR along with the centres of AICRP on cotton have developed, standardized and validated a few strategies that can establish sustainable cotton production systems for high yields and low production costs. These are High density planting systems, Bt varieties, long linted desi cottons, canopy management for square and boll retention management, cover cropping green manure crop and incorporation; intercropping, integrated pest management (IPM) and insect resistance management (IRM) for pest, disease and weed management and timely termination and crop residue management. Results under these studies are enumerated below.

**1. High density planting system (HDPS)**

* Over 75 semi-compact genotypes were evaluated at over a wide range of plant densities ranging from 30 x10 cm to 90 x10 cm at 13 locations in 11 states over a six year period from 2010-11 to 2015-16. Results indicated that under rainfed conditions, the available semi-compact *G. hirsutum* genotypes can be planted at two or three times the currently recommended density (of 50000-55000 plants $ha^{-1}$) adopted spacing of around 20,000 plants $ha^{-1}$.
* The average yield improvement over the recommended (55000 plants $ha^{-1}$) in these genotypes was around 25 per cent.
* The plants matured a week to 10 days earlier under high density planting (Venugopalan *et al.,* 2013).
* The nutrient requirement under HDPS would be 25 per cent extra (over the recommended dose of 60:30:30) but was lower than that recommended for hybrids. The nutrient uptake efficiency improved under HDPS but there was no improvement in nutrient utilization efficiency.
* Results also indicated significant interactions between genotypes and spacing, genotypes and soil depth, Genotypes and growing condition (rainfed/irrigated), spacing and soil depth and spacing and location. Suraj, which is widely cultivated under HDPS is a medium duration, semi-compact genotype. On deep soils Suraj performs well at 75 x10 cm under rainfed (assured rainfall) or even at 90 x10 cm under irrigated conditions. On medium deep soils 60 x10 cm was the best spacing for Suraj. On the contrary, early and more compact genotypes like PKV081 and Anjali need to be planted at 45x10 cm on shallow soils and 60x10 cm on medium and deep soils. Genotype NH 615 performed best at 60x10 cm on medium deep soils on deltaic soils of Guntur, genotype ADB 39 gave best yield when planted at 75x10 cm under rainfed conditions. The genotypes identified for HDPS in various states and the recommended spacings are presented in Table 2.

**Table 2 : Semi compact genotypes of *G. hirsutum* for HDPS-different locations**

| S.N. | State | Variety | Spacing(cm) |
|---|---|---|---|
| 1. | Gujarat | G Cot 16, Suraj | 60x10 |
| 2. | Haryana | F2383, CSH 3075 | 67.5x10 |
| 3. | Madhya Pradesh | JK 4, Suraj | 60x10 |
| 4. | Maharashtra | PKV 081,<br>NH 615, Suraj | 45x10,<br>60x10<br>and 75x10 |
| 5. | Karnataka | DSC 99, ARBC 64 | 90x10 cm |

| | | | |
|---|---|---|---|
| 6. | Orissa | BS 279, BS 30 | 60x10 |
| 7. | Andhra Pradesh | ADB 39, NDLH 1938, ADB 538 | 60x10 |
| 8. | Tamil Nadu | Anjali, Suraj, KC3 | 60x10 and 75x10 |
| 9. | Punjab | F 2383 | 67.5x10 |

More than 5000 participatory demonstrations of this technology were undertaken. In a drought year, drought in 2015-16, trials in 12 cotton growing states (1294 farmers in 190 villages) recorded average yields of 5.91 q acre$^{-1}$ with Cost: Benefit ratio of 1:1.5.

**2. Deployment of Bt-varieties as alternatives to Bt hybrids**

Based on a multiplication evaluation, 8 Bt varieties were approved for commercialization in 2017 (Table 3).

**Table 3: Bt varieties approved for cultivation in different states**

| S.N. | Name of the variety | Area of adaptation |
|---|---|---|
| 1 | CICR Bt 6 (RS 2013) | Haryana |
| 2 | PAU Bt1 | Punjab & Rajasthan |
| 3 | ICAR-CICR Bt 9 | Maharashtra |
| 4 | ICAR-CICR Bt 14 (CPT 2) | Maharashtra |
| 5 | ICAR-CICR GJHV 374 Bt | Maharashtra |
| 6 | ICAR-CICR PKV 081 Bt | Maharashtra |
| 7 | ICAR-CICR Rajat Bt | Maharashtra & South Rajasthan |
| 8 | ICAR-CICR SurajBt | Central Zone - Maharashtra, Gujarat, Madhya Pradesh |

These varieties have several desirable traits such as short duration; sympodial architecture; early maturing with synchronous flowering and fruiting; high initial root and shoot vigor; high harvest index and can be a boon to resource poor farmers under irrigated and rainfed conditions.

**3. HDPS of long linted G *arboretum* varieties for marginal soils under rainfed conditions**

* Our trials with long linted arboreums under HDPS indicated that genotypes - PA 740, PA 785, PA 812, and PA 255 gave significantly higher seed cotton yield than Ajeet BG II planted under normal density. The yields were higher under shallow soils (Vertic Inceptisols) than on deep soils (Vertisols)
* These genotypes had longer fibre length than Ajeet 155 BG II. The genotypes PA 812, PA 760, PA 785, PA 08 and PA 528 recorded Spinning Consistency Index values SCI values higher than 130 as against 130 by Ajeet 155.

**4. Adoption of conservation tillage, cover crops, intercrops, crop residue recycling / mulching to reduce soil loss, improve soil health**

* At Nagpur, soil moisture conservation were achieved through ridge-furrow, bio-mulch with sesbania and sunhemp and BBF (Figure 3). The yield realized in control (without conservation was 1198 kg ha$^{-1}$) and the yield gain (over control) was 120 kg ha$^{-1}$ with Pusa Hydrogel (single dose) @ 3.25kg ha$^{-1}$, 300 kg ha$^{-1}$ with ridges-furrow system, 299 kg ha$^{-1}$ with bio-mulch of Sesbania

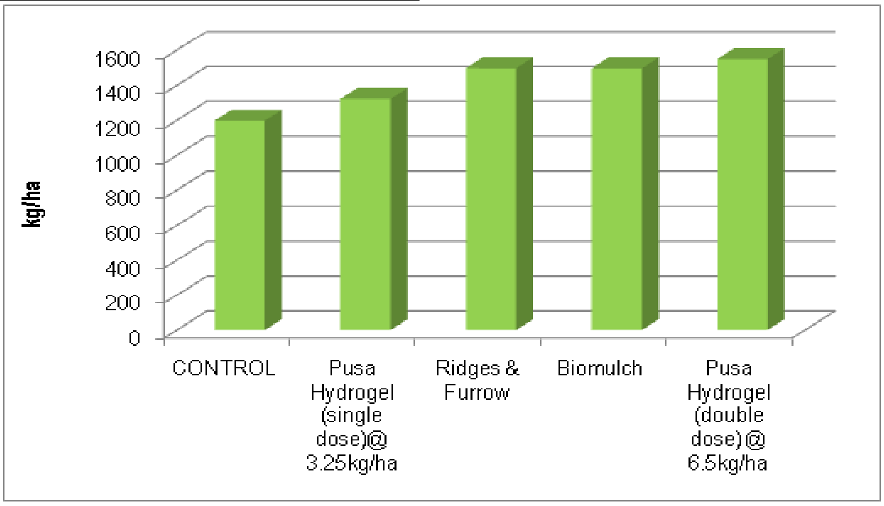


**Figure 3: Effect of soil moisture conservation measures on seed cotton yield in Vertisols of Nagpur**

and 350 kg ha$^{-1}$ with Pusa Hydrogel (double dose) @ 6.5kg ha$^{-1}$. Pusa hyderogel was not economical. At Coimbatore, ridge-furrow method gave significantly higher seed cotton yield (2900 kg ha$^{-1}$) over raised bed method (2820 kg ha$^{-1}$) and control (2370 kg ha$^{-1}$).

* Intercropping with short duration legumes provides adequate nitrogen exactly at the flowering and boll formation stage. Legume intercropping provides a wide range of beneficial natural enemies that assist in IPM, thereby reducing the need for insecticides. Cultivation of legume intercrops in between rows in high density systems or in crop rotation reduces the need for repeated weeding and can assist in conservation agriculture. Among the different intercrops evaluated, clusterbean, groundnut, cowpea and soybean were found promising on rainfed black soils.

5. **Mulching to reduce soil temperature, smother weeds and conserve soil moisture**

6. **Canopy management to modify plant architecture**

* A growth retardant, Mepiquat chloride @ 50 gai ha$^{-1}$ in 2 equal splits at peak squaring (55-65 days stage) and peak flowering (75-85 days stage) was effective in modifying crop architecture and bringing in the desired canopy. Its application reduced plant height, curtailed excessive vegetative growth, ensured a more efficient translation of photosynthates to bolls, increased boll weight and further enhanced yield at high planting densities (Venugoplan *et al.*, 2016).

7. **Precision input management including synchronized nutrient delivery, to improve factor productivity.**

8. **Selective mechanization of sowing, weeding and picking to reduce cost of weeding**

* Inclined plate planter was found effective for planting cotton under HDPS.

**Roadmap to increase the cotton yield and cotton farmers income**

Productivity improvement in cotton to 700 kg ha$^{-1}$ through effective containment of on-farm and off farm losses.

* Deployment of compact , short duration (150 days), sucking pest tolerant Bt *G. hirsutum* - varieties in 20 per cent area – North India, South and Central India (with supplementary irrigation), assured rainfall regions.
* Deployment of Hybrids in 60 per cent area- Well drained soils and irrigated regions of Gujarat, deltaic soils of South India and valleys of Central India and deep soils with assured rainfall (rainfed)
* Deployment of Desi cotton: 20 per cent area under long-linted (drylands of Central and South India) and 5per cent short staple desi in N. India and North east.
* High Density Planting System (1-2 lakh plants ha$^{-1}$ - varieties and 30,000 plants ha$^{-1}$ - hybrids) of Bt varieties and desi cotton
* Widespread adoption of Best Management Practices (HDPS, legume based cropping systems, residue recycling, microbial consortia, intercropping, soil moisture conservation, Integrated Pest Management/ Insecticide Resistance Management) through skill improvement of farmers through demonstrations of best management practices.
* Effective utilization of cotton stalk for charcoal, pellets / briquettes, substrate for mushroom rearing, vermi-compost etc., to improve farm income by 5 – 10 per cent.
* Timely dissemination weather based advisories and scientifically validated cotton crop care advisories to cotton farmers through ICT tools.
* Intensification of efforts to augment the production of extra long staple cotton to reduce imports

## CONCLUSION

Low cotton yields, limited opportunity for diversification and wide year to year fluctuation are serious obstacles in doubling the income of rainfed cotton farmers. BMPs conclude that short duration, early maturing varieties with high harvest-index and heat tolerance, timely planting, selective deployment of high density planting systems and *desi* cotton varieties, conservation tillage and crop residue management practices and synchronized nutrient delivery systems can be helpful in adapting to climatic uncertainties, improve cotton yields, increase input use efficiency and reduce production costs.New short duration varieties, both long-lint Desi (*Gossypium arboreum*) and Bt-varieties have great potential to enhance yields at low production costs in consonance with ecology and environment. Farmers need to adopt these yield enhancing, cost saving technologies and switch over to more sustainable production systems to reduce risks, improve farm income under the uncertain climate change scenario.

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# Soil Sustainability and Quality Assessment from Long Term Fertilizer Experiments: A Step Forward to Improve and Revive Crop Productivity and Soil Health

**R. H. Wanjari[1] and Muneshwar Singh[2]**

## ABSTRACT

Soil health, the underlying principle in the use of this term is that it is not just an inert, lifeless growing medium, which modern farming tends to represent, rather it is a living, dynamic and ever-so-subtly changing whole environment. It turns out that soils highly fertile from the point of view of crop productivity are also lively from a biological point of view. Soil health is the condition of the soil in a defined space and at a defined scale relative to a set of bench marks that encompass healthy functioning. Soil health encompasses the state of soil in terms of biological, physical and chemical properties. Soil health is very vital because there is a fatigue in soil in terms of productivity, quality and sustainability. Concerns are growing about the long-term sustainability of agriculture. Both the over- and under-application of fertilizers and the poor management of resources not only deteriorated soil health but also raised environmental concerns. In developing countries, harsh climatic conditions, population pressure, land constraints and ignoring traditional soil management practices have often reduced soil fertility (Kumwenda *et al*., 1996). It is often said that Indian agriculture is operating at a negative nutrient balance of about 10 million tonnes of NPK. This is to happen when nutrient supplies through external sources are less than nutrient removal by crops from the soil. Negative balances could well indicate that the soils are being mined and that farming systems are unsustainable over the long-term. Because agriculture is a soil-based industry that extracts nutrients from the soil, effective and efficient approaches to slowing the pace of most of the nutrients essential for plant growth and that the way in which nutrients are managed will have a major impact on plant growth, soil fertility and agricultural sustainability. Farmers, researchers, fertilizer industry and governments all have an important role to play in this context. Integrated nutrient management (INM) is not a new concept. It is an age-old practice when almost all the nutrient needs were met through organic sources to supply secondary and micronutrients besides primary nutrients. Keeping this in view, in India long term fertilizer experiments were started in September, 1970. In this paper the research findings emerged out of these experiments are narrated.

J. B. Lawes and J. H. Gilbert started nine long-term experiments between 1843 and 1856, these are called the *'Rothamsted Classical Experiments'*. In India also a series of long-term fertilizer experiments were established at different locations in the country in the beginning of 20th century. During late sixties high yielding varieties (HYV) were introduced which later on proved to be the main pillar of Green Revolution. Intensification of agriculture under irrigated condition resulted in acceleration of nutrient mining from soil to harness the potential of the HYV for long term. Under this situation, it has become imperative to maintain nutrient supply in sufficient quantity without external use of fertilizers. In view of these emerging compulsions the Indian Council of Agricultural Research initiated the "All India Coordinated Research Project on Long-Term Fertilizer Experiments (AICRP-LTFE)" in September 1970. The purpose of conducting long term fertilizer experiments at fixed sites in different agroecological zones (AEZ) with important cropping systems was not only to monitor the changes in soil properties and yield responses and soil environment due to continuous application of plant nutrient inputs through fertilizers and organic sources. The results from LTFEs further used in developing strategies and policies in national perspectives as well as management of fertilizers to improve soil quality and to minimize environment degradation. Thus, the thrust of AICRP- LTFE is on productivity, sustainability and environment safety.

In India, fertiliser found to be a key factor to enhance agricultural production and its use has increased rapidly in the last few decades, mainly due to adoption of

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high yielding and nutrient responsive cultivars in large parts of the country. Adoption of fertilisers has largely replaced traditional practices, such as recycling of crop residues and application of organic manures. Introduction of irrigation further enhanced fertiliser use. However, the likely high fertilizer cost in years to come, deterioration of soil health as a result of imbalanced use of nutrients and questions of sustainability have led to a renewed interest in the use of organic manure. Now, sustainability refers to the maintenance and/or enhancement of productivity on a long-term basis continuously through integrated land management (Randhawa, 1994). No system of agriculture will be sustainable unless the productivity and quality of the soil are continuously maintained (Kanwar, 1994). Low and declining soil fertility are the main causes of low productivity under intensive cropping systems (Nambiar and Ghosh, 1982; Nambiar and Abrol, 1989; Nambiar, 1994; Swarup and Wanjari, 2000). Nevertheless, integrated effect of both organic manure and fertilizer sources of plant nutrients has been found to be quite promising not only in maintaining higher productivity but also in providing stability in soil fertility and crop production. In this context the results of the long-term fertilizer experiments provide an opportunity to measure sustainable management systems in agriculture (Rasmussen, 1998). These are records of the past and may serve as early warning systems for the future (Dawe *et al*., 2000). In order to monitor the changes in soil fertility and yield responses due to continuous application of plant nutrient from fertilisers and organic manures, the first step in analysing the results of fertilizer in long-term experiment is to identify one or more characters to be used as an index of crop sustainability.

## MATERIAL AND METHODS

The long term fertiliser experiments (LTFEs) started in September, 1970 and they have fixed set of treatments. These LTFEs covers four major soil types, eleven agro-ecological zones with predominant cropping systems under vivid climatic situations.The long term fertilizer experiments were being conducted in intensive and irrigated system with predominant cropping systems of different agro-ecological zones exists in India. The experimental sites are located in different State Agricultural Universities (SAUs) and ICAR Institutes (Table 1). The details of soil type, cropping system, agro-ecological sub-region (AESR), latitude, longitude and altitude of different experimental sites spread over country. There are 10 treatments in each experiment. These are: 50 per cent optimal NPK dose; 100 per cent optimal NPK dose; 150 per cent optimal NPK dose; 100 per cent optimal NPK dose + hand weeding; 100 per cent optimal NPK dose + Zinc or lime; 100 per cent optimal NP; 100 per cent optimal N; 100 per cent optimal NPK + FYM; 100 per cent optimal NPK (Sulphur free/sulphur source); Control with a provision of one or two additional treatments that may be of local or regional interest. The treatments are replicated four times in a randomized block design.

### Impact of Long term Fertilizer and Manures on Soil Health

#### Soil Physical Properties

Physical properties are important to assess the soil that help in deciding the management required for particular activities. The data clearly indicated that bulk density of soil decreased considerably on continuous application of FYM along with the recommended dose of fertilizers (NPK) as compared to that of control where no fertilizer was applied. Increase in mean weight diameter (MWD) on application of nutrient with organic manure compared to control is due to incorporation of more residual biomass. The largest reduction in bulk density, improvement in MWD and water holding capacity on application of FYM confirms that organic matter play an important role in maintaining physical condition of soil. Among various soil physical properties, bulk density (BD) has been widely considered as a critical parameter for soil health assessment, largely due to its relationships with other soil state (strength and porosity) and rate (moisture retention and flow characteristics) variables. In long-term experiments a reduction in BD due to application of manure have been observed (Singh and Wanjari, 2007; Singh and Wanjari, 2012). Soil aggregation in general composes soil structure which greatly influenced with addition of organic sources.

#### Soil Biological Properties

Biological properties of soil are equally important in assessing the soil health. In soil all the nutrients are mediated through biochemical reactions which are performed by the soil organisms. The activities of the organisms in soil give an idea about the soil condition.

**Table 1. Details of AICRP-LTFE experimental sites in India**

| Location | Soil Type | Taxonomic Class | Cropping system | AESR | Latitude | Longitude | Altitude |
|---|---|---|---|---|---|---|---|
| Akola | Vertisols | TypicHaplustert | Sorghum-wheat | 6.2 | 20º42' N | 77º02' E | 307 m |
| Bangalore | Alfisols | KandicPaleustalf | Fingermillet-maize | 8.1 | 12º58' N | 77º35' E | 930 m |
| Barrackpore | Inceptisols | TypicEutrochrept | Rice-wheat | 15.1 | 22º45' N | 88º26' E | 9 m |
| Coimbatore | Inceptisols | VerticUstopept | Finger millet-maize | 8.1 | 11º02' N | 76º59' E | 426 m |
| Jabalpur | Vertisols | TypicChromustert | Soybean-wheat | 10.1 | 23º10' N | 79º59' E | 411 m |
| Jagtial | Inceptisols | TypicTropaquept | Rice-rice | 7.2 | 18º48' N | 78º55' E | 263 m |
| Junagadh | Vertisols | VerticUstochrept | Groundnut-wheat | 2.4 | 21º30' N | 70º26' E | 61 m |
| Ludhiana | Inceptisols | TypicUstochrept | Maize-wheat | 4.1 | 30º54' N | 75º48' E | 247 m |
| New Delhi | Inceptisols | TypicUstochrept | Maize-wheat | 4.1 | 28º 38' N | 77º 09' E | 228 m |
| Palampur | Alfisols | TypicHapludalf | Maize-wheat | 14.3 | 32º07' N | 76º31' E | 1472 m |
| Pantnagar | Mollisosl | Typic Hapludoll | Rice-wheat | 14.1 | 29º05' N | 79º52' E | 243 m |
| Pattambi | Alfisols | TypicHaplustalf | Rice-rice | 19.2 | 10º48' N | 76º12' E | 25 m |
| Raipur | Vertisols | TypicHaplusterts | Rice-wheat | 11.0 | 21º17' N | 81º45' E | 695 m |
| Ranchi | Alfisols | TypicHaplustalf | Soybean-wheat | 12.3 | 23º23' N | 85º23' E | 625 m |
| Udaipur | Inceptisols | TypicUstochrept | Maize-wheat | 4.2 | 24º36' N | 73º44' E | 577 m |

AESR = Agro-Ecological Sub-Region (Source: Wanjari and Singh, 2010)

Biological properties are influenced by nutrient management practices. Soil organic matter acts as substrate for soil macro and micro flora and fauna. These organisms maintain their population by using organic matter as substrate. The data on population of various organism under different treatment indicated that irrespective of nutrient combination, balance application of chemical fertilizer resulted increase in population of bacteria, fungi and actinomycetes. Data further indicated that imbalance use of nutrient say N alone had negative effect on population compared with balanced treatment but superior to control. Incorporation of biomass in larger quantity through root and stubble added to soil as a result of higher productivity in plot receiving balanced nutrient application favoured microbial population.

Dehydrogenase activity in soil has been considered as an index of overall microbial activity. Hydrolysis of fluorescein diacetate (FDA) appears to be important among the primary producers, bacteria and fungi. This hydrolysis is mediated by a number of enzymes like proteases, lipases and esterase, at a single time. Microbial biomass carbon (MBC) is another biological indicator which gives status of soil. The data demonstrated that absence of P and K reduced microbial biomass carbon may be due to imbalance of nutrient status in soil.

**Soil Chemical Properties**

**Soil pH**

Soil pH is an intrinsic property that takes longer time to change. In general, data indicated that application of fertilizer over the years resulted in slight reduction in pH of soil in Alfisols. But effect of application of 100 per cent N alone lowered the soil pH in Alfisols group of soils. Soil pH data further revealed decline at several other centres also where initial soil pH was in alkaline range. Decline in soil pH irrespective of initial status is due to acidic nature of nitrogenous fertilizer.

**Electrical Conductivity**

Across the treatments the EC of soil remain more or less stable with little variation. The EC is below critical limit for crop growth at all the sites. Therefore, it is not adversely affecting the crop growth.

**Soil Organic Carbon (SOC)**

Soil organic carbon is key soil parameter to assess physical condition as well as source- sink for nutrients depending upon soil parameters to form good structure for root growth, infiltration of water and exchange of air for respiration of roots. Data indicated that growing of crops with balance nutrient management option resulted increase in organic carbon at almost all the centres. The increase in SOC was found to be more under balanced and integrated nutrient management. The increase in SOC on application of fertilizer is due to increase in quantity of residual biomass as a result of higher production. More increase in SOC under balanced and integrated nutrient management support the statements that under these treatments productivity is proportionately greater than other treatments. Therefore, in these treatments amount of residual biomass added is relatively larger which is reflected in SOC.

**Soil Nutrient Status**

**Available N**

Balanced and integrated use of nutrient resulted increase in N status at most of the sites, if not then at least maintained. Imbalance use of nutrient or their less application could not maintain the available status of N with respect to initial. Data further indicated that cropping system also played a role in maintaining the N status. For example, soybean based cropping system at Jabalpur and Parbhani resulted significant improvement in available N status in all the treatments. The larger N content in residual biomass of soybean could be a reason for increase in soil N content in all treatments. Here, it could be supplemented that at these sites increase in SOC was also in larger quantity. Rainfall and soil type are also important factors which decide N status of soil. In-spite of soybean based system at Ranchi improvement in available N was not recorded. In general, integrated use of nutrient, incorporation of lime/FYM, exclusive use of FYM resulted increase in available status of N in soil. Comparison of trend of available N with SOC under different management practices, it is found that available N status followed trend similar to SOC.

**Available P**

Regular supply of P to crop is essential to sustain the productivity over the years. Irrespective of soils, all crops have shown response to applied P. In Alfisols, P is second most important nutrient after K. Available P soil status indicated built up in soil P. Continuous application of fertilizer P resulted increase in P status and relatively more increase was noted in Alfisols compared to Inceptisols and Vertisols of Jabalpur and Akola. This could be because of calcareous nature of Vertisols soil. Even after 40 years increase in P status in soils of Coimbatore is of very low order. These soils are rich in $CaCO_3$ and fixation of P as calcium phosphate could be possible reason for low available P status in-spite of application of similar amount of P. Incorporation of FYM resulted for the increase in available P status at all sites. This is because of additional supply of P and secondly application of FYM during decomposition produces organic complex which block P fixation sites. Decline in available P status in 100 per cent N and control treatment is obviously due to no application of P in fertilizer schedule.

**Available K**

Potassium is also most required element by majority of crops. Even though K is not a constituent of plant but required in larger quantity almost equal to nitrogen. Available K status revealed decline in Vertisols and associated soils (Jabalpur, Akola, Junagadh) whereas in Alfisols (Bangalore, Bhubaneshwar, Pattambi) reverse trend was noted. However, an increase in estimates of available K were noted in other soils like Mollisols of Pantnagar and Inceptisols of New Delhi and Ludhiana. It indicates that absence of K over a long period invariably resulted in decline of K status irrespective of soil type. In Alfisols, sufficiently larger amount of K need to be added to soil to maintain the crop productivity and soil fertility. Thus, it is the reason that crop show response to applied K in Alfisols.

**Available Micronutrients**

Growing of high yielding varieties along with high use of irrigation and fertilizers lead to emergence of micro and secondary nutrients. Similarly, increase in cropping intensity and application of high analysis fertilizer accelerated the mining of nutrients from soil including micronutrient. In addition to this, little/no use of organic matter further aggravated the magnitude of micronutrient deficiency in crop. Amongst the micronutrients, Zn cation was found highly deficient in different pockets of country.

Perusal of micronutrient status indicated that Zn level has gone down to critical limit at Jabalpur and Akola wherein crop may respond to applied Zn in near future. Mollisols at Pantnagar Zn is one of the deficient element and available status is at the verge of inadequacy. Otherwise at other centres still the level of Zn is far above the critical limit. As far as available status of Cu, Fe and Mn is concerned, these nutrients are in sufficient range in almost all soils and crops are not expected to suffer in near future. Application of organic manure irrespective of quantity and location improved available status of all micronutrients (Zn, Cu, Fe and Mn). The balanced application of nutrient is also taking care of these cations by mobilization from the reserve source during decomposition residual biomass added to soil. Thus, from the results it is concluded that incorporation of organic matter (FYM, GM) not only maintained the supply of these nutrients but also improved their status.

**Crop Productivity**

Crop yield is the reflection of soil fertility and crop growth and weather situation. Yield trends revealed gradual decline in yield of major crops like rice, wheat and soybean compared to initial productivity. It implies that more attention has to be required to these factors. The crop productivity follows the order as NPK+FYM> 150 per cent NPK> 100 per cent NPK+Zn or lime> 100 per cent NPK> 100 per cent NP> 100 per cent N > control. In Alfisols, 100 per cent N is found to be more deleterious than control.

**Sustainability**

The data on sustainable yield index (SYI) indicated that imbalance nutrient application resulted in decline of SYI values indicating unfit for continuation (Table 2). On the contrary, balance nutrient application found sustainable compared to imbalance treatments. The integrated nutrient management gave highest index values across the soil type and cropping systems (Table 2).

**Soil Quality**

Soil quality index (SQI) indicate the condition of soil at that point of time under a particular management practice. More is the SQI better is the soil quality. The SQI was estimated by using principal component analysis (PCA) and using their relative contribution in productivity. In general, the balanced nutrient application recorded higher SQI values than imbalanced treatments. However, in Alfisols NPK+ FYM, NPK+ lime gave relatively higher SQI than control which suggest that balanced application of nutrient improved soil quality. Incorporation of organic manure further improved the soil quality. In these treatments yields were also sustained at higher level at almost all the locations suggesting that balanced use of nutrient not only sustained the yield but also improved the soil quality.

**Revival of Soil Fertility and Crop Productivity**

The imbalance nutrient application over the years not only declined the crop yields but also soil fertility. Such deteriorated soils can be revived by application of manure or amendments in addition to the recommended dose of fertilizers. Taking into account such emerging factors, corrective measures were considered in the form of superimposition of treatments at respective LTFE sites. The superimposition of FYM and lime moderates soil pH and improved soil organic carbon.Application of both FYM and lime resulted in improvement of soil fertility, moderated soil condition and eventually resulted into higher crop yields. These superimposition has also overall improved physical, chemical and biological conditions of soils. Thus, application of FYM or lime improved the productivity of almost all the crops across the major soils. However, the results are conspicuous in all the crops grown on Alfisols.

## CONCLUSION

Nitrogen or NP alone has deleterious effect on crop yield and soil quality, the effects are more pronounced in acid soils such as Alfisols. The application of NPK along with FYM improves the physical, chemical and biological properties of soil and thereby enhanced soil health. The deteriorated soil and crop productivity through imbalance nutrient application can be revived either with amendments and FYM application.Thus, integrated use of fertilizer along with manure is vital for sustaining crop productivity and soil health over the years. Balance and integrated nutrient management is the option to maintain crop productivity, sustainability and soil health

**Table 2. Sustainable yield index (SYI) estimates for long term fertilizer experiments in India**

| Centre | Crop | Control | N | NP | 100 % NPK | 150 % NPK | NPK+Zn | NPK+FYM | NPK+Lime |
|---|---|---|---|---|---|---|---|---|---|
| Barrackpore | Rice | 0.15 | 0.29 | 0.34 | 0.35 | 0.41 | 0.30 | 0.40 | - |
| | Wheat | 0.11 | 0.30 | 0.36 | 0.38 | 0.47 | 0.37 | 0.41 | - |
| Pantnagar | Rice | 0.13 | 0.39 | 0.43 | 0.41 | 0.38 | 0.47 | 0.50 | - |
| | Wheat | 0.15 | 0.46 | 0.51 | 0.51 | 0.50 | 0.56 | 0.62 | - |
| Ludhiana | Maize | 0.03 | 0.18 | 0.24 | 0.29 | 0.32 | 0.37 | 0.44 | - |
| | Wheat | 0.14 | 0.43 | 0.63 | 0.70 | 0.76 | 0.74 | 0.78 | - |
| Palampur | Maize | 0.01 | 0.07 | 0.15 | 0.35 | 0.36 | 0.34 | 0.53 | 0.47 |
| | Wheat | 0.04 | 0.05 | 0.15 | 0.28 | 0.28 | 0.27 | 0.42 | 0.40 |
| Ranchi | Soybean | 0.10 | 0.01 | 0.21 | 0.49 | 0.47 | - | 0.62 | 0.60 |
| | Wheat | 0.03 | 0.02 | 0.29 | 0.35 | 0.36 | - | 0.43 | 0.41 |
| Bangalore | F. Millet | 0.06 | 0.06 | 0.07 | 0.50 | 0.61 | - | 0.56 | 0.49 |
| | H. Maize | 0.00 | 0.01 | 0.01 | 0.21 | 0.22 | - | 0.27 | 0.25 |
| New Delhi | Maize | 0.25 | 0.34 | 0.38 | 0.44 | 0.50 | 0.47 | 0.51 | - |
| | Wheat | 0.38 | 0.58 | 0.67 | 0.74 | 0.81 | 0.76 | 0.82 | - |
| Coimbatore | F. Millet | 0.08 | 0.12 | 0.36 | 0.37 | 0.41 | 0.36 | 0.46 | - |
| | Maize | 0.06 | 0.09 | 0.36 | 0.39 | 0.43 | 0.41 | 0.47 | - |
| Junagadh | Groundnut | 0.22 | 0.20 | 0.21 | 0.27 | 0.30 | 0.28 | - | - |
| | Wheat | 0.27 | 0.23 | 0.37 | 0.40 | 0.43 | 0.38 | - | - |
| Udaipur | Maize | 0.34 | 0.50 | 0.62 | 0.67 | - | 0.72 | 0.79 | - |
| | Wheat | 0.26 | 0.45 | 0.54 | 0.60 | - | 0.62 | 0.69 | - |
| Raipur | Rice | 0.60 | 0.43 | 0.61 | 0.61 | 0.68 | 0.62 | 0.66 | - |
| | Wheat | 0.26 | 0.38 | 0.68 | 0.67 | 0.81 | 0.69 | 0.75 | - |
| Jagtial | Kharif Rice | 0.32 | 0.46 | 0.52 | 0.55 | 0.57 | 0.54 | 0.58 | - |
| | Rabi Rice | 0.24 | 0.31 | 0.45 | 0.46 | 0.50 | 0.46 | 0.48 | - |
| Jabalpur | Soybean | 0.13 | 0.14 | 0.26 | 0.32 | 0.30 | 0.29 | 0.35 | - |
| | Wheat | 0.14 | 0.15 | 0.49 | 0.54 | 0.56 | 0.53 | 0.59 | - |
| Akola | Sorghum | 0.01 | 0.15 | 0.21 | 0.29 | 0.40 | 0.33 | 0.40 | - |
| | Wheat | 0.00 | 0.13 | 0.18 | 0.31 | 0.41 | 0.31 | 0.00 | - |
| Parbhani | Soybean | 0.23 | 0.25 | 0.36 | 0.41 | 0.44 | 0.39 | 0.44 | - |
| | Safflower | 0.29 | 0.35 | 0.37 | 0.45 | 0.49 | 0.44 | 0.49 | - |
| Pattmbi | Kharif/Rice | 0.33 | 0.44 | 0.46 | 0.48 | 0.50 | - | 0.61 | 0.49 |
| | Rabi/Rice | 0.47 | 0.58 | 0.62 | 0.68 | 0.69 | - | 0.82 | 0.67 |
| Bhubneshwar | Kharif/Rice | 0.26 | 0.31 | 0.34 | 0.46 | 0.51 | - | 0.00 | - |
| | Rabi/Rice | 0.23 | 0.33 | 0.48 | 0.55 | 0.61 | - | 0.00 | - |

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# Effect of Organic Manures on Yield and Essential Oil of Sweet Flag in Konkan Region

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## ABSTRACT

*Acorus calamus* (Sweet flag) is one of the endangered medicinal plants mostly grown in wild without much attention. Also it is in high demand in pharmaceutical and perfumery industries. Hence, a study was undertaken of 2017-18 to assess the possibility of optimizing its rhizome yield and essential oil recovery by different source of organic manures based on recommended doses of nitrogen under field condition. Significantly maximum rhizome yield (4674.7 kg ha$^{-1}$) and essential oil recovery (1.87%) was obtained with Farm yard manure 100 per cent of RDN. Hence this study illustrates the possibility of optimizing rhizome yield and essential oil content of *A.calamus* through organic manures only.

*Acorus calamus* Linn. is a tall perennial wetland monocot plant from the Acoraceae family and commonly known as Sweet flag in English, *Vacha* in Sanskrit and *Vekhand* in Hindi and Marathi. Sweet flag is a semiaquatic perennial herb with a stout midrib, with creeping and many branched aromatic rhizomes. It consists of long creeping rhizomes which spread out just below the surface of the soil. The rhizomes are whitish pink internally, cylindrical in shape. Leaves are free, alternate, green and wavy having thin testa which is cylindrical in shape. (Prakash *et al.,* 2015).

*Acorus calamus* is one of the endangered medicinal plant; mostly growing in wild form without much attention (Singh and Nongmaithem, 2013) and found near swamps and banks of perennial wetlands in Asia, Europe, and North America. It is indigenous to the marshes of the mountains of India and found in Kashmir, Shirmaur (Himachal Pradesh), Manipur and Naga Hills (Shetty *et al.,* 2015). It is cultivated throughout India, ascending to an altitude of about 2200 metres. It is regularly cultivated in the Koratagere taluka of Karnataka state in an area of 100 acres and the annual production is 400 tonnes of dried rhizomes (Lokesh, 2004).

Demand for the crop material of sweet flag is a derived demand and that is based on Ayurvedic medicines. This has increased substantially during the recent years due increased dependence on Ayurvedic medicines. The dramatic increase in exports of medicinal plants in the past decade upholds the worldwide demand for these products as well as in traditional health systems. (Deshpande, *et al,* 2006)

Medicinal plants are natural resources as they are unique, indispensable and an estimate of their availability is complex. These provide a good source of income if cultivated aggressively and traded, as the demand is fast increasing. According to National Medicinal Plant Board (NMPB), the annual demand of *Acorus* roots by the herbal industries and crude drug producers in all over India nearly 500-1000 M.T.. The current price of *Acorus* roots is Rs.100 Kg$^{-1}$.

*Acorus calamus* contains yellow aromatic volatile oils; â-asarone and á-asarone are the major constituent in the leaves (27.4 to 45.5%), whereas, acorenone is dominant in the rhizomes (20.86 %) followed by isocalamendiol (12.75%). Monoterpene hydrocarbons, sequestrine ketones, (trans or alpha) asarone (2,4,5- trimethoxy -1- propenylbenzene), and â asarone (cis - isomer) and eugenol have also been identified. *A. calamus*is also a source of alkaloids, falvanoids, gums, lecitins mucilage, phenols, quinine, saponins, sugars, tannins and triterpenes, etc. (Prakash *et al.* 2015).

Extracts of different parts and essential oil of *Acorus calamus* are widely used in pharmaceuticals, traditional systems of medicines for a number of ailments. The species are used in traditional medicine for the treatment of cough, epilepsy, mental ailments, chronic

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diarrhoea, dysentery, bronchial catarrh, skin diseases, intermittent fevers, and glandular and abdominal tumours (Paithankar *et al.,* 2011). Different drug types with varying content of B-asarone were obtained from *Acorus calamus.* The plant extracts shows various biological activities including as anti-bacterial, anti-fungal, insecticidal, nematicidal, antiulcer and cytoprotective activity, anti-inflammatory, anticonvulsant (Kumar and Vandana, 2013).

For a long crop duration (about 10 months) and its rhizomatous nature, it requires heavy input of fertilizers. But, continuous use of inorganic chemical fertilizer negatively affects soil environment and pollutes underground water (Naguib, 2011). It is essential to reduce indiscriminate use of inorganic chemical fertilizer and to simultaneously increase the use of organic manures which improve soil, plant health. Therefore, the present investigation was carried out to assess organic manures on rhizome yield and essential oil of Sweet flag in Konkan region.

## MATERIAL AND METHODS

The study was conducted in the experimental farm of College of Forestry, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, District Ratnagiri of Maharashtra during 2017-2018. The study area is located between $17^0$ 45" N and $73^0$ 12" E. The climate of Dapoli is warm and humid. During study period maximum and minimum temperature ranged from 19.3 to 31.4$^0$C, respectively. The total rainfall received during the period of study was 3605.6 mm in 109 days. The relative humidity during the crop period ranged 71.52 to 93.54 per cent.

The experiment was laid out in Randomised Block Design. For these objectives,Vermicompost,Farm yard manure, Leaf litter, Neem cake were used. Total five treatments having three different source of Nitrogen such as 75 per cent, 100 per cent and 125 per cent were given to plots.The treatment was replicated thrice. A total 42 numbers of rhizomes were planted at 30 cm x 30 cm spacing in every treatment (July 2017). The treatment plot size was 2.1 m x 1.8 m. For the rhizome yield, the plants were harvested after 270 days in the month of April 2018 from all the plots rhizomes were cleaned and taken the fresh weight. The essential oil was extracted and carried out by soxhlet's extraction method at temperature (100$^0$C) at extraction time of 4-5 hrs.

## RESULTS AND DISCUSSION

The results of experiment on the biomass yield and the essential oil content are presented in Tables 1. Data on rhizome yield, irrespective of organic manures was highest $T_5$ Farm yard manure 100 per cent of RDN (4674.7 kg ha$^{-1}$) when harvested after 270 days (Table 1) followed by $T_4$ Farm yard manure 75 per cent of RDN (4632.7 kg ha$^{-1}$). The variation in yield of sweet flag as affected by different levels of application of organic manures and date of planting was also reported by Jarman (2009), Thakur and Agrawal (2009) and Tiwari *et al.,* (2012). The plant age had significant effect on total fresh yield and leaves and rhizomes fresh weights (Osman *et al*., 2008). Fresh and dry yield of sweetflag is significantly affected by FYM treatment (Lokesh, 2004). FYM and GA3 are beneficial for increasing the rhizome yield of Sweet flag (Datta *et al*., 2009).

**Table 1. Effect of organic manure on rhizome yield and oil content of Sweet flag**

| Treatment | Rhizome Yield (kg ha$^{-1}$) | Oil content (%) |
|---|---|---|
| $T_1$ Vermicompost 75 % of RDN | 2189.50 | 1.45 |
| $T_2$ Vermicompost 100 % of RDN | 2420.10 | 1.42 |
| $T_3$ Vermicompost 125 % of RDN | 2119.20 | 1.48 |
| $T_4$ Farm yard manure 75 % of RDN | 4632.70 | 1.85 |
| $T_5$ Farm yard manure 100 % of RDN | 4674.70 | 1.87 |
| $T_6$ Farm yard manure 125 % of RDN | 4011.70 | 1.80 |
| $T_7$ Leaf litter 75 % of RDN | 2513.00 | 1.60 |
| $T_8$ Leaf litter 100 % of RDN | 2474.70 | 1.56 |
| $T_9$ Leaf litter 125 % of RDN | 2030.90 | 1.63 |
| $T_{10}$ Neem cake75 % of RDN | 1592.60 | 1.05 |
| $T_{11}$ Neem cake100 % of RDN | 1675.00 | 1.17 |
| $T_{12}$ Neem cake125 % of RDN | 2020.40 | 1.12 |
| $T_{13}$ 75 % of GRDF | 3342.00 | 1.73 |
| $T_{14}$ 100 % of GRDF | 3282.70 | 1.77 |
| $T_{15}$ 125 % of GRDF | 4598.10 | 1.81 |
| SE (m) $\pm$ | 3.98 | 0.01 |
| CD at 5% | 11.52 | 0.04 |

In the present investigations (Table 1) it has been observed that the various organic manures significantly affected the oil content in rhizome of *A.calamus*. Maximum oil content was recorded in with $T_5$ - FYM 100% + RDN (1.87%) followed by $T_4$ i.e. Farm yard manure 75 per cent of RDN (1.85%). Essential oil recovery has been reported in the range of 1.1-3.3per cent for super critical carbon dioxide extraction (SFE) and 1.0-2.4 per cent in the case of simultaneous distillation and extraction (SDE) (Gretsusnikova *et al*., 2009, Andola *et al*., 2012). Organic manures significantly effect the oil content of *A. calamus* (Lokesh 2004).

## CONCLUSION

From the present findings, it may be concluded that increased rhizome yield and essential oil content of *Acorus calamus* can be obtained with the application of Farm yard manure @ 100 per cent recommended dose of nitrogen. Hence, FYM is beneficial for increasing the rhizome yield and essential oil content of Sweet flag.

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# Productivity of Castor, Economics and Energetics as Influenced by Castor Genotypes, Plant Geometry and Nitrogen Management under *Rainfed* Condition of Vidarbha

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## ABSTRACT

A field experiments was conducted during *Kharif* 2008-09 and 2009-10 on a silty clay loam soil at the Agronomy Department Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola to study the yield of castor , economics and energetics as influenced by castor genotypes, plant geometry and nitrogen management under rainfed . The treatment consisted of two genotypes (AKC-1 and GCH-4) and three plant spacing (90 cm x 45 cm, 120 cm x 45 cm and 90 cm x 90 cm) and four nitrogen management (125 % N, 100 % N, 75 % N +25 % FYM+ *Azospirillium*). The experiment was laid out in split plot design and replicated thrice. All recommended practices were adopted for better crop growth during the two seasons. Across the crop growth period rainfall amounted to 371.9 and 376.6 mm during 2008-09 and 2009-10, respectively. Seed yield, biological yield of castor, energy productivity , GMR, NMR were significantly higher in castor hybrid GCH 4 over AKC-1 when planted at 90 cm x 45 cm and nitrogen management with 125 per cent N (75 kg N $ha^{-1}$) followed by 100 per cent N (60 kg N $ha^{-1}$) in two split with basal dose of 40 kg $P_2O_5$and 20 kg $K_2O$. The highest seed yield of castor hybrid recorded by GCH 4 (2855 kg $ha^{-1}$) with plant density of 90 cm x 45 cm (24619 plants $ha^{-1}$)

Castor (*Ricinus communis* L.) is a high value industrial crop, belonging to the family Euphorbiaceae. It is non edible due to the presence of toxic protein ricin in seed. The oil content in castor seed ranges from 48 to 55 per cent out of which 90 per cent is extracted. India has highest area 11.48 lakh ha with higher productivity 1666 kg $ha^{-1}$ and meet about 90 per cent of world's requirement of castor oil. India is earning about Rs.2253 crores foreign exchange through export of oil and derivatives with high level of demand rising annually at 3-5 per cent per annum. The castor oil is unique in terms of its dominance of a single fatty acid ricinoliec acid (90 %) due to which all the special properties of oil and its uses are ascribed. There are varied applications for castor oil and its derivatives that have widespread application in many industries like lubricant, paint, pharmaceutical, textiles etc. Castor is one of the important oilseed crop having high plasticity suiting to wide range of soil environments and capacity to adjust its growth according to moisture availability conditions of the soil.

Castor is nitro-positive and indeterminate in growth habit. For maximizing the yield potential of hybrids/ varieties, proper fertilizer use plays an important role. Bio-fertilizers are an important component of IPNS particularly in rainfed condition where farmers are tending to rely either on 'no cost' or 'low cost' technologies. In addition to plant population, adequate fertilization is congenial for getting higher yields of castor. The chances of multiple harvests of beans are more and it may bring assured income to the farmers even under remaining moisture conditions.Abiotic stress cause extensive losses to agricultural production worldwide (Boyer,1982 and Bray *et al*, 2000). Among those stresses, the availability of nitrogen (N) and water are considered as two of the major limiting factors in crop growth development and final economic yield (Glass, 2003). Information on suitable nitrogen management to castor is lacking in this region anditcan be grown as contingent crop in Vidarbha. Hence, an investigation was done to study the yield of castor, economics and energetics as influenced by Castor Genotypes, Plant geometry and Nitrogen management under rainfed.

## MATERIAL AND METHODS

The study was conducted during kharif 2008-09 and 2009-10 on a silty clay loam soil at the Agronomy Department Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola to study the impact of nutrient management on soil fertility, crop productivity and nutrient

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uptake by castor genotypes under different plant geometry. The treatment consisted of two genotypes (AKC-1 and GCH-4) and three plant geometry (90 cm x 45 cm, 120 cm x 45 cm and 90 cm x 90 cm) and four nitrogen management (125 per cent N, 100 per cent N, 75 per cent N+25 per cent N through (FYM) and 50 per cent N+ 25 per cent N through (FYM) + *Azospirillium*). The experiment was laid out in split plot designand replicated thrice. The castor crop was dibbled on 20 and 21 July 2008 and 2009 respectively. All recommended practices were adopted for better crop growth during two seasons. The experimental data were collected during the course of investigation were statistically analyzed with split plot design programme on computer by adopting standard statistical techniques of analysis of variance (Panse and Sukhatme 1985). Across the crop growth period rainfall amounted to 371.9 and 376.6 mm during 2008-09 and 2009-10, respectively. Picking wise seed yield of castor and total seed yield $ha^{-1}$ castor was recorded. Economics were worked out with prevailing market price and the energetic in castor werecalculated on the basis of inputs required $ha^{-1}$ for castor production.Energy input was calculated from sowing to harvesting pertaining to each treatment of individual experiment of castor crop. It was estimated by Mega Joule (MJ) $ha^{-1}$with reference to the standard value prescribed by the Mittal and Dhawan (1998). Energy output workout by using the item energy values of each treatment. Energy output was workout from Castor seed and stalk of castor crop.

## RESULTS AND DISCUSSION

**Seed yield of Castor**

The seed yield of castor was obtained from primary, secondary and tertiary spikes and recorded significantly highest yield.

**Effect of castor genotypes**

Seed yield obtained from primary, secondary and tertiary spikes in GCH-4 was significantly higher compared to AKC-1(Table 1). The seed yield was 2052 and 2712 and 2381 kg $ha^{-1}$ during 2008 and 2009 in pooled respectively $ha^{-1}$. As compared to AKC-1, GCH-4 yielded more 13.4 per cent (2008-09), 8 per cent (2009-10) and 10.2 per cent in pooled.Superior yields with hybrid GCH-4 were due to better expression of growth characters and yield components. The genotypes of GCH-4 produced higher seed yield also had higher number of spikes, capsules and seed yield $plant^{-1}$. These results are in agreement with findings of Patel *et al.,* (1991) and Kiran (2003).

**Effect of plant geometry**

Regulating the plant densities to an optimum level is essential to exploit the yield potential by allowing the inter and intra row spacing competitiveness without any detriment to total output. In the present investigation, seed yield from primary, secondary and tertiary spikes and total seed yield with a population of 24691 plants $ha^{-1}$ (90 cm x 45 cm) was significantly higher compared to 18518 and 12345 plants $ha^{-1}$ in both the years as well as pooled data. Lower seed yield was obtained with lower population $ha^{-1}$ though the seed yield per plant was highest could not compensate the yield $ha^{-1}$. It indicates seed yield per plant increases with decrease in plant density but decrease in seed yield will be compensated by increased plant population.

The yield increase with $S_1$ over $S_3$ and $S_2$ over $S_3$ was 53.5 and 19 per cent in 2008 and 40.7 and 15.7 per cent in 2009 and 46.0 and 17.2 per cent under pooled data (Table 1).

Optimum plant spacing (90 x 45 cm) had reduced the competition between plants for moisture, nutrients, light and space hence seed yield was increased. The results are in accordance with the findings of Raghavaiah and Sudhakar Babu (2000) and Sudha Rani (2007).

**Effect of nitrogen management**

Seed yield from primary, secondary and tertiary spikes and total seed yield revealed that seed yield increased with increase in nitrogen level up to 80 kg $ha^{-1}$ (125 % N through inorganic) during both the years as well as in pooled data. Application of 125 per cent N through inorganic (80 kg N $ha^{-1}$) significantly increased the total seed yield compared to 50 per cent N + 25 per cent N through ( FYM) and seed treatment with *Azospirillium*.

But it was at par with 100 per cent N (60 kg N $ha^{-1}$) and 75 per cent N + 25 per cent N through FYM and seed yield was lowest with $N_4$ (50 % N+ 25% N (FYM) + *Azospirillium*). The per cent increase in total seed with $N_1$, $N_2$, $N_3$ over $N_4$(50 % N+ 25 % N (FYM)+ Azospirillium was 19.9, 15.0 and 8.3 per cent, respectively. Nitrogen is known to be required formation of vegetative structure of nutrient absorption and photosynthesis, formation of reproductive structures and determination of sink strength and the production of assimilates to fill the economically important sink

**Interaction effect**

Interaction between castor genotype and plant geometry in respect of total seed yield was found significant (Table 2). The combination of $S_1xV_1$ (2855 kg $ha^{-1}$) in pooled mean was significantly superior over rest of the treatments. It indicates the optimum plant density of 90 cm x 45 cm spacing with GCH-4 found to be best for highest yield.

**Biological yield**

The biological yield of castor was 5889, 7019 and 6449 kg $ha^{-1}$ during 2008-09, 2009-10 and pooled data respectively (Table 1). The highest biological yield during 2009-10 was due to receipt of good amount of rainfall during development of secondary and tertiary spikes capsules and seed development.

**Effect of castor genotypes**

Differences in biological yield due to genotypes were significant during 2008 and 2009 and in pooled data. GCH-4 recorded significantly highest biological yield (6242 kg $ha^{-1}$) over AKC-1 (5497 kg $ha^{-1}$). Superior biological yields with hybrid GCH-4 were due to better expression of growth characters particularly dry matter weight per plant and yield components as compared to variety AKC-1 and better utilization of resources by GCH-4.

**Effect of planting geometry**

Biological yield was produced significantly highest with a population of 24619 plants $ha^{-1}$ (90 x45cm) followed by (120 x 45 cm) and (90 x 90 cm) in both the years as well as in pooled mean over two years. The highest pooled mean of biological yield (7465 kg $ha^{-1}$) with 90 x 45 cm and lowest (5517 kg $ha^{-1}$) biological yield with 90 x 90 cm. It might be due to optimum utilization of resources by narrow spacing (90 x 45 cm) produced maximum dry matter weight and ultimately maximum biological yield.

**Effect of nitrogen management**

The highest biological yield was significantly recorded with 125 per cent N (80 kg $ha^{-1}$) over rest of the treatments in 2008-09 and in pooled data but which was at par with 100 per cent N (60 kg $ha^{-1}$) during 2008-09. Significantly highest biological yield (7026 kg $ha^{-1}$) was recorded with 125 per cent N (80 kg $ha^{-1}$ through inorganic) in pooled data. This was due to highest plant height and greater dry matter accumulation.

**Interaction effect**

Adequate nitrogen supply has promoted the growth and increased yield attributes such as number of spikes and capsules per spikes and seed weight of castor resulted in the highest seed yield, as noticed in the presentation confirms the documented evidence of Hafeezuddin Khan (1974), Mathukia and Modhwadia (1995).

**Harvest Index**

**Effect of castor genotypes**

Differences in harvest index due to different genotypes were not significant in both the years. Numerically GCH-4 recorded the maximum harvest index over AKC-1. GCH-4 recorded highest harvest index which was due to the efficiency of that genotypes to accumulate dry matter and partition the accumulated dry matter to the sink.

**Effect of plant geometry**

Harvest index obtained with 24619 plants $ha^{-1}$ (90 cm X45 cm) was significantly highest over other densities. The maximum harvest index percent with narrow spacing (90 cm x 45 cm) during both the years as well as in pooled data.

**Effect of nitrogen management**

The harvest index did not differ significantly due to nitrogen management in both the years as well as pooled over two years. The increased number of capsules per plant, which increased the seed yield/ plant resulted higher harvest index and it increased with increasing dose of nitrogen.

**Table 1 : Seed yield, biological yield (Kg ha$^{-1}$) and H.I. (per cent) of Castor and pooled means as influenced by different treatments**

| Treatments | Seed yield (Kg ha$^{-1}$) | | | Biological yield (Kg ha$^{-1}$) | | | Harvest index (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2008 | 2009 | Pooled | 2008 | 2009 | Pooled | 2008 | 2009 | Pooled |
| **Main Plot** | | | | | | | | | |
| **A) Genotypes (V)** | | | | | | | | | |
| Vl - AKC-1 | 1810 | 2509 | 2159 | 5497 | 6192 | 6144 | 32.9 | 36.9 | 34.9 |
| V2 - GCH-4 | 2052 | 2712 | 2381 | 6242 | 7245 | 6754 | 32.6 | 37.4 | 35 |
| S.E. (m) ± | 14.9 | 16.3 | 10.9 | 29.6 | 40.7 | 32.4 | 0.2 | 0.25 | |
| CD at 5 % | 47.1 | 51.4 | 34.3 | 93.9 | 128.4 | 102.1 | 0.6 | 0.78 | |
| **B) Plant Geometry (S)** | | | | | | | | | |
| S1 - 90x45 cm | 2387 | 3093 | 2739 | 6890 | 8040 | 7465 | 34.7 | 38.6 | 36.65 |
| S2 - 120x45 cm | 1851 | 2542 | 2196 | 5736 | 6896 | 6316 | 32.4 | 36.9 | 34.65 |
| S3 - 90x90 cm | 1555 | 2197 | 1875 | 5016 | 6119 | 5567 | 31.1 | 35.9 | 33.5 |
| S.E. (m) + | 18.2 | 19.9 | 13.3 | 36.2 | 49.9 | 39.7 | 0.3 | 0.30 | |
| CD at 5% | 57.6 | 62.9 | 42 | 114.2 | 157.0 | 125.0 | 0.9 | 0.95 | |
| **Sub plot- Nitrogen management (N)** | | | | | | | | | |
| Nl - 125 % N | 2090 | 2829 | 2462 | 6382 | 7670 | 7026 | 32.7 | 36.9 | 34.8 |
| N2 - 100 % N | 2009 | 2673 | 2361 | 6106 | 7201 | 6654 | 32.8 | 37.0 | 34.9 |
| N3 - 75 N + FYM (25 % N) | 1885 | 2565 | 2225 | 5731 | 6845 | 6288 | 32.8 | 37.4 | 35.1 |
| N4 - 50 N + FYM + Azos. | 1734 | 2373 | 2053 | 5302 | 6357 | 5829 | 32.6 | 37.3 | 34.95 |
| S.E. (m) ± | 39.7 | 152 | 43 | 143 | 161 | 116 | 0.7 | 1.04 | |
| CD at 5 % | 114.0 | 436 | 124 | 412 | 463 | 334 | 2.1 | 3.00 | |
| **Interaction effect** | | | | | | | | | |
| V x S | | | | | | | | | |
| S.E. (m) + | 25.9 | 28.2 | 18.8 | 51.3 | 70.6 | 56.1 | 0.4 | 0.43 | |
| CD at 5 % | 82.0 | 89.0 | 59.4 | 162 | NS | 176.8 | NS | NS | |
| SxN | | | | | | | | | |
| S.E. (m) ± | 56.1 | 96.4 | 61.0 | 202.8 | 228 | 164.2 | 1.0 | 1.48 | |
| CD at 5 % | NS | NS | NS | NS | NS | NS | NS | NS | |
| V x N | | | | | | | | | |
| S.E. (m) + | 68.7 | 118 | 70.7 | 248.3 | 279 | 201.2 | 1.2 | 1.81 | |
| CD at 5 % | NS | NS | NS | NS | NS | NS | NS | NS | |
| V x S x N | | | | | | | | | |
| S.E. (m) ± | 97.2 | 166 | 145.7 | 351.2 | 395 | 284.5 | 1.8 | 2.6 | |
| CD at 5 % | NS | NS | NS | NS | NS | NS | NS | NS | |
| General Mean | 1931 | 2610 | 2270 | 5881 | 7019 | 6449 | 32.7 | 37.2 | 34.95 |

**Table 2: Seed yield (pooled) as influenced by Interaction between genotype and plant geometry**

| Treat-ments | Seed yield (kg ha$^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2008 | | | 2009 | | | Pooled | | |
| | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 |
| AKC-1 | 2250 | 1663 | 1516 | 2995 | 2391 | 2141 | 2622 | 2027 | 1828 |
| GCH-4 | 2524 | 2038 | 1594 | 3191 | 2692 | 2253 | 2855 | 2365 | 1923 |
| S.E. (m) ± | 25.9 | | | 28.2 | | | 18.8 | | |
| CD at 5 % | 82.0 | | | 89.0 | | | 59.4 | | |

**Table 3: Biological yield (pooled) as influenced by interaction between genotype and plant geometry**

| Treatments | Biological yield (kg ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 2008 | | | Pooled | | |
| | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ |
| AKC-1 | 6470 | 5148 | 4873 | 7183 | 5854 | 5395 |
| GCH-4 | 7310 | 6324 | 5159 | 7746 | 6777 | 5740 |
| S.E. (m) ± | 51.3 | | | 56.1 | | |
| C.D. at 5% | 162 | | | 176.8 | | |

**Economics**

**Effect of castor genotypes**

Genotype GCH-4 recorded significantly highest gross monetary returns (Rs.41035 ha$^{-1}$), net monetary returns (Rs 18917 ha$^{-1}$) in 2008-09 and GMR (Rs. 54239 ha$^{-1}$), NMR (Rs. 32122 ha$^{-1}$) in 2009-10 and in pooled GMR (Rs. 47637 ha$^{-1}$) and pooled NMR (Rs. 25519 ha$^{-1}$) (Table 4). Benefit cost ratio was 1.85, 2.45 and 2.16 in 2008-09 and pooled mean, respectively. The higher the gross returns due to higher seed yield of castor hybrid GCH-4.

**Effect of plant geometry**

GMR and NMR were significantly influenced with different plant geometry. Gross monetary returns were Rs.47736 ha$^{-1}$, Rs.61857 ha$^{-1}$ and Rs 54796 ha$^{-1}$ significantly highest with a spacing 90 x 45 cm (24619 plant ha$^{-1}$) during 2008-09, 2009-10 and pooled data, respectively. Net monetary returns were Rs. 25605, Rs.39726 and Rs. 32665 ha$^{-1}$ accrued with the spacing 90 x 45 cm followed by 120 x 45 cm and minimum GMR, NMR with wider spacing (90 x 90 cm). The higher gross and net returns might be due to higher seed yield and higher plant population ha$^{-1}$.

**Effect of nitrogen management**

Economics of different levels of nitrogen management revealed that the highest gross returns Rs 41912 , Rs. 56580, respectively during 2008-09, 2009-10 and pooled data, respectively were significantly accrued with 125 per cent N ( 80 kg ha$^{-1}$ through inorganic) but which was at par with 100 per centN (60 kg ha$^{-1}$). However, significantly highest NMR of Rs. 21228 ha$^{-1}$, Rs. 35896 ha$^{-1}$ and Rs. 28652 ha$^{-1}$ during 2008-09, 2009-10 and pooled data respectively was recorded. Sarda Devi (1999) reported that higher level of N of castor accrued maximum B:C ratio.

**Interaction effect**

Interaction between genotype and plant geometry in pooled analysis (Table 5) indicated highest gross returns (Rs. 57152 ha$^{-1}$) were received with GCH-4 when planted at 90 x 45 cm (24619 plant ha$^{-1}$). Similarly net returns (Rs. 34600 ha$^{-1}$) in pooled data. It proved higher

**Table 4: Economics of Castor as influenced by various treatments during 2008-09 and 2009-10.**

| Treatments | GMR(Rs ha1) | | | NMR(Rs ha1) | | | B:C | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2008 | 2009 | pooled | 2008 | 2009 | pooled | 2008- | 2009 | pooled |
| **Main plot** | | | | | | | | | |
| **A) Genotypes (V)** | | | | | | | | | |
| $V_1$ - AKC-1 | 36193 | 50177 | 43185 | 14682 | 28666 | 21674 | 1.68 | 2.33 | 2.02 |
| $V_2$ - GCH-4 | 41035 | 54239 | 47637 | 18917 | 32122 | 25519 | 1.85 | 2.45 | 2.16 |
| S.E. (m) ± | 298 | 326 | 218 | 298 | 326 | 218 | | | |
| CD at 5 % | 941 | 1028 | 618 | 941 | 1028 | 618 | | | |
| **B) Plant Geometry (S)** | | | | | | | | | |
| $S_1$- 90x45 cm | 47736 | 61857 | 54796 | 25605 | 39726 | 32665 | 2.15 | 2.79 | 2.49 |
| $S_2$- 120x45 cm | 37011 | 50835 | 43923 | 15241 | 29064 | 22152 | 1.70 | 2.33 | 2.03 |
| $S_3$- 90x90 cm | 31095 | 43933 | 37514 | 9554 | 22392 | 15973 | 1.44 | 2.03 | 1.75 |
| S.E. (m) ± | 366 | 399 | 267 | 366 | 399 | 267 | | | |
| CD at 5 % | 1153 | 1259 | 840 | 1153 | 1259 | 240 | | | |
| **Sub plot-Nitrogen Management (N)** | | | | | | | | | |
| $N_1$ - 125 % N | 41912 | 56580 | 49246 | 21228 | 35896 | 28562 | 2.02 | 2.73 | 2.38 |
| $N_2$ - 100 % N | 40178 | 53469 | 46824 | 19944 | 33235 | 26589 | 1.98 | 2.64 | 2.31 |
| $N_3$ - 75 N + FYM(25 %N) | 37694 | 51317 | 44505 | 14447 | 28069 | 21258 | 1.62 | 2.21 | 1.91 |
| $N_4$ - 50 N + FYM + Azospirillium | 34671 | 47467 | 41069 | 11579 | 24375 | 17977 | 1.50 | 2.05 | 2.00 |
| S.E. (m) ± | 793 | 1363 | 863 | 793 | 1363 | 863 | | | |
| CD at 5 % | 2279 | 3917 | 2480 | 2279 | 3971 | 2480 | | | |
| **Interaction effects** | | | | | | | | | |
| V x S | | | | | | | | | |
| S.E. (m) ± | 517 | 565 | 377 | 517 | 565 | 377 | | | |
| CD at 5 % | 1630 | 1780 | 1188 | 1630 | 1780 | 1188 | | | |
| V x N | | | | | | | | | |
| S.E. (m) ± | 1121 | 1927 | 1221 | 1121 | 1927 | 1221 | | | |
| CD at 5 % | NS | NS | NS | NS | NS | NS | | | |
| S x N | | | | | | | | | |
| S.E. (m) ± | 1347 | 2361 | 1495 | 1347 | 2361 | 1495 | | | |
| CD at 5 % | NS | NS | NS | NS | NS | NS | | | |
| V x S x N | | | | | | | | | |
| S.E. (m) ± | 1943 | 3338 | 2114 | 1943 | 3338 | 2114 | | | |
| CD at 5 % | NS | NS | NS | NS | NS | NS | | | |
| GM | 38614 | 52208 | 45411 | 16800 | 30394 | 23597 | 1.76 | 2.39 | 2.09 |

**Table 5: GMR as influenced by interaction between genotype and plant geometry**

| Treatments | GMR (Rs ha$^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2008 | | | 2009 | | | Pooled | | |
| | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ |
| AKC-1 | 44991 | 33268 | 30320 | 59890 | 47825 | 42815 | 52441 | 40545 | 36568 |
| GCH-4 | 50480 | 40755 | 31870 | 63823 | 53845 | 45050 | 57152 | 47300 | 38460 |
| S.E.m$\pm$ | 517 | | | 565 | | | 377 | | |
| CD at 5% | 1630 | | | 1780 | | | 1188 | | |

**Table 6: NMR as influenced by Interaction between genotype and plant geometry**

| Treatments | NMR (Rs ha$^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2008 | | | 2009 | | | Pooled | | |
| | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ |
| AKC-1 | 23280 | 11771 | 8989 | 31879 | 26333 | 21484 | 30730 | 19055 | 15236 |
| GCH-4 | 27929 | 18704 | 10119 | 40127 | 31794 | 23299 | 34600 | 22152 | 15973 |
| S.E. (m) $\pm$ | 517 | | | 565 | | | 377 | | |
| CD at 5 % | 1630 | | | 1780 | | | 1188 | | |

returns with higher plant density due to higher seed yield ha$^{-1}$. $V_2XS_1$ was found to be remunerative (Table 6).

**Energetics**

**Effect of genotype**

Significant variation in the energy output, output: input ratio and energy use efficiency was due to genotypes were observed (Table 7). The highest energy output was obtained with GCH-4 over AKC-1 due to higher seed and stalk yield of castor. Similarly maximum output: input ratio and energy use efficiency was recorded with GCH-4 over ACK-1 during both the years and in pooled data.

**Effect of plant geometry**

Differences in energy output, output: input ratio were found to be significant in respect of various plant geometry. Energy output was maximum in plant geometry of 90 x 45 cm than other plant. Similar trend was noticed in output input ratio and energy use efficiency.

**Effect of nitrogen management**

Energy output: input ratio was significantly influenced with nitrogen management. The highest energy output was obtained with 125 per cent N (80 kg N ha$^{-1}$) and which is at par 100 per cent N and lowest with 50 per cent N +25 per cent N (FYM)+ Azospirillium. However,output: input ratio was significantly maximum with 100 per cent N (60 kg N ha$^{-1}$) followed by 50 per cent N + 25 per cent N FYM + Azospirillium and similar trend was with energy use efficiency. It might be due to higher seed and stalk yield which produced maximum energy output.

**Interaction effect**

GCH-4 when planted at 90 x 45 cm recorded highest output energy value and maximum output: input ratio

## CONCLUSION

For getting maximum economic returns castor genotypes GCH- 4 could be sown at planting geometry of 90 x 45 cm ( 24615 plants ha$^{-1}$) with an application of 75 kg N ha$^{-1}$ in two splits and basal dose of 40 kg $P_2O_5$ and 20 kg $K_2O$ ha$^{-1}$ under rainfed condition of Vidarbha region.

**Table 7: Energetics in castor as influenced by various treatments during 2008-09 and 2009-10.**

| Treatments | Energy output(MJ Kg1) | | | Energy input (MJ Kg1) | Energy output: input ratio | | | Energy use (g MJX103) efficiency |
|---|---|---|---|---|---|---|---|---|
| | 2008 | 2009 | Pooled | | 2008 | 2009 | Pooled | |
| **Main plot** | | | | | | | | |
| **A) Genotypes (V)** | | | | | | | | |
| $V_1$ - AKC-1 | 111610 | 139821 | 125716 | 10171 | 11.0 | 13.7 | 12.35 | 60.4 |
| $V_2$ - GCH-4 | 127119 | 146970 | 137045 | 10171 | 12.5 | 14.7 | 13.6 | 66.4 |
| S.E. (m)± | 582 | 636 | 512 | | 0.047 | 0.08 | 0.06 | |
| CD at 5 % | 1835 | 2006 | 1612 | | 0.147 | 0.25 | 0.18 | |
| B) **Plant Geometry (S)** | | | | | | | | |
| $S_1$ - 90x45 cm | 140727 | 166377 | 153552 | 10364 | 13.6 | 16.1 | 14.8 | 72.0 |
| $S_2$ - 120x45 cm | 116198 | 141929 | 129063 | 10225 | 11.4 | 13.9 | 12.6 | 61.8 |
| $S_3$ - 90x90 cm | 101170 | 121882 | 111526 | 9923 | 10.2 | 12.7 | 11.5 | 56.3 |
| S.E. (m)± | 713 | 779 | 627 | | 0.06 | 0.10 | 0.07 | |
| CD at 5 % | 2247 | 2457 | 1995 | | 0.18 | 0.31 | 0.22 | |
| **Sub plot** | | | | | | | | |
| **Nitrogen Management** | | | | | | | | |
| $N_1$ - 125 % N | 129549 | 157866 | 143707 | 11452 | 11.3 | 13.8 | 12.5 | 61.3 |
| $N_2$ - 100 % N | 123977 | 148347 | 136162 | 9928 | 12.4 | 14.9 | 13.7 | 66.8 |
| $N_3$ - 75 N + FYM (25 % N) | 116358 | 141188 | 128772 | 10106 | 11.5 | 14.0 | 12.7 | 62.1 |
| $N_4$ - 50 N + FYM + Azospirillium | 107575 | 126182 | 116899 | 9197 | 11.7 | 14.2 | 12.9 | 63.3 |
| S.E. (m) ± | 2740 | 3025 | 2216 | | 0.27 | 0.30 | 0.22 | |
| CD at 5 % | 7874 | 3696 | 6369 | | 0.28 | 0.87 | 0.63 | |
| CV% | | | | | | | | |
| **Interaction effects** | | | | | | | | |
| V x S | | | | | | | | |
| S.E. (m) ± | 1009 | 1103 | 886 | | 0.08 | 0.14 | 0.10 | |
| CD at 5 % | 3179 | 3475 | 2793 | | 0.25 | 0.44 | 0.32 | |
| V x N | - | - | - | - | - | - | - | |
| S.E. (m) ± | 3875 | 4279 | 3134 | | 0.41 | 0.43 | 0.3 | |
| CD at 5 % | NS | NS | | | | | | |
| S x N | | | | | | | | |
| S.E. (m) ± | 4745 | 5241 | 3839 | | 0.47 | 0.52 | 0.38 | |
| CD at 5 % | NS | NS | | | | | | |
| V x S x N | | | | | | | | |
| S.E. (m) ± | 6711 | 7421 | 5429 | | 0.90 | 0.74 | 0.54 | |
| CD at 5 % | NS | NS | | | | | | |
| GM | 119365 | 143395 | 131380 | 10171 | 11.7 | 14.2 | 13.0 | 63.3 |

**Table 8: Energy output as influenced by interaction between genotype and plant geometry**

| Treatments | Energy output MJ ha$^{-1}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2008 | | | 2009 | | | Pooled | | |
| | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ |
| AKC-1 | 132199 | 104302 | 98330 | 163114 | 134852 | 121499 | 147656 | 119577 | 109914 |
| GCH-4 | 149255 | 128093 | 104011 | 169460 | 149005 | 122265 | 159447 | 138549 | 113138 |
| S.E.m$\pm$ | 1009 | | | | | | 886 | | |
| CD at 5 % | 3179 | | | | | | 2793 | | |

**Table 9 : Energy output input ratio as influenced by interaction between genotype and plant geometry**

| Treatments | Energy output input ratio | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2008 | | | 2009 | | | Pooled | | |
| | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ |
| AKC-1 | 12.8 | 10.2 | 9.9 | 15.7 | 13.2 | 12.3 | 14.25 | 11.79 | 11.11 |
| GCH-4 | 14.4 | 12.5 | 10.5 | 16.4 | 14.6 | 13.9 | 15.40 | 13.56 | 11.82 |
| S.E.m$\pm$ | 0.08 | | | 0.14 | | | 0.10 | | |
| CD at 5 % | 0.25 | | | 0.44 | | | 0.32 | | |

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# Soil Fertility Management Through Pigeonpea Based Intercropping System - *Bt* Cotton Rotation with Conservation Tillage Practices Under Rainfed Condition of Vidarbha Region

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## ABSTRACT

Conservation Agriculture techniques involve minimum soil disturbance providing a soil cover through crop residue or other crop cover and rotation for achieving higher productivity , while protecting the natural resources and environment. An integrated nutrient management with moisture conservation has influence on chemical and biological properties of soil for sustainable production. An experiment was conducted at Department of Agronomy farm Dr. Panjarao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra) during 2010-11 to 2015-16 (Six years with three rotations of pigeonpea intercropping followed by Bt cotton). As Bt cotton demands continues supply of moisture and nutrients at the time of boll development stage and which intercropping system will provide organic matter to improve the moisture supply and nutrients during stress period. The treatments consists of tillage practices, conventional and minimum tillage with three cropping systems during first year and rotated with rainfed Bt cotton with four nutrient management levels in next season.FRBD was used for first year and split plot design was used for second year.

Pigeonpea equivalent yield (PEY) and economics were not influenced by tillage practices with inter cropping system during first year followed by Bt cotton . The highest mean pigeonpea equivalent yield (1779 kg $ha^{-1}$) was obtained from pigeonpea +soybean 1:2. However, maximum biomass was available for recycling from pigeonpea +sunnhemp 1:2 cropping system where sunhemp was green manured and shed biomass (leaf litter) of pigeonpea also added (6195 kg $ha^{-1}$) for next season crop. The mean seed cotton yield (1387 kg $ha^{-1}$) was significantly highest, when pigeonpea +sunnhemp was grown in previous year. Seed cotton yield of Bt cotton was highest (1367 kg $ha^{-1}$) with nutrient management through shed biomass of previous year intercropping + 100 per cent RDF was applied to cotton. Bulk density was decreased with minimum tillage and when pigeonpea + sunnhemp (1:2) was grown.The highest values of organic carbon, soil microbial biomass carbon and NPK, when pigeonpea + sunhemp (1:2) was grown in previous year and also improved after shed biomass + 5 0 per cent RDF + 50 per cent RDN through vermi compost to cotton.

Cotton, soybean and pigeonpea are the important crop of the Vidarbha region of Maharashtra. Pigeonpea based intercropping system is widely accepted by farmers of this region in different row proportions with soybean as per farmers convenience and also growing cotton/ soybean on same piece of land to earn income every year.Growing of crops one after another without giving due consideration to nutrient requirement has resulted in decline in soil fertility (Ghosh *et al*., 2003). Intercropping of pulses and oilseeds is one of the ways to increase pulse and oilseed production as it is more advantageous than sole cropping of both pulses and oilseeds (Louduraj *et al*., 1998). Pigeonpea and soybean intercropping system not only provides organic matter to the soil but also proved to be profitable cropping system. To break the life cycle of pest, diseases and weeds and to maintain soil health crop rotation is must.Farmers could not apply recommended FYM to maintain soil fertility. Farmers facing the problems in rearing of cattle because of non-availability of fodder and drinking water throughout the year in rainfed ecosystem. *Bt* cotton demands continues supply of moisture and nutrients at the time of boll development stage.

An integrated nutrient management with moisture conservation has influence on chemical and biological properties of soil for sustainable production. Residue recycling is an important component to increase level of organic carbon in the soil.

Tillage based conventional agriculture is assumed to have led to soil organic matter decline, water runoff and soil erosion (Derpsch *et al.,*1991)and other

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manifestation of physical,chemical and biological soil degradation (Benites,2008). Besides minimizing soil erosion,conservation tillage can promote input saving through reduced usage of tillage equipment. This lower tillage aspects decrease fuel consumption, promotes longer machinery life, allows utilization of reduced horse power implements and lower requirement. However, these benefits can be slightly offset by increased chemical weed control costs. Conservation tillage greatly reduces leaching of fertilizer, pesticide and herbicides in the ground water. Conservation tillage improves activity of earthworm and other soil microflora. It also increases soil infiltration rate and reduces soil evaporation there by it increases soil water storage. Due to higher residues in soil it will improve soil organic carbon content,it gives smothering effect to weed and by it increases yield of crops. To conserve and optimum the use of natural resources with profitability as guiding factors of sustainability farming practices have to be redesigned. Hence, it was felt necessary to identify suitable intercropping system, which supply *in-situ* indigenous organic material to improve the organic carbon status and fertility of soil and productivity of rainfed Bt cotton with different tillage practices and integrated nutrient management.

## MATERIAL AND METHODS

Conservation Agriculture techniques involve minimum soil disturbance providing a soil cover through crop residue or other crop cover and rotation for achieving higher productivity, while protecting the natural resources and environment. Based on the principles of Conservation Agriculture, the field experiment was conducted on same site for six years at Department of Agronomy farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra) during 2010-11 to 2015-16 (Six years with three rotations of pigeonpea intercropping followed by *Bt* cotton). Treatment consists of tillage practices, conventional and minimum tillage with three inter cropping systems during first year *viz*, pigeonpea + soybean (1:2 ), pigeonpea + soybean (1:5) which is farmers practice and pigeonpea +sunnhemp (1:2). The sunhemp was buried after 45 days after sowing in two rows of pigeonpea row in conventional tillage and under minimum tillage, sunhemp was mulched in between two rows of pigeonpea. This system was rotated with rainfed *Bt* cotton with four nutrient management levels i .e. shed biomass of previous cropping system, shed biomass(leaf litter) + 50 per cent RDN through prepared vemicomposting (VC) from left over pigeonpea and soybean straw,shed biomass + 50 per cent RDN through VC + 50per cent RDF and shed biomass+ 100 per cent RDF (60:30:30 NPK kg $ha^{-1}$). The experiment was laid out in FRBD for first year where, Pigeonpea based cropping system with tillage practices were taken. Split plot design was used for second year where, nutrient management was imposed on previous cropping system with tillage practices. The soil of experimental field was well drained, clayey in texture, moderately high in available nitrogen (210 kg $ha^{-1}$), moderate in available phosphorus (15.4 kg $ha^{-1}$), rich in available potassium (318 kg $ha^{-1}$) with slightly alkaline in reaction. In conventional tillage practices were adopted ploughing +harrowing + sowing and two hoeing and under minimum tillage harrowing before sowing+ sowing + recommended herbicide + one hoeing was adopted. Pigeonpea variety PKV Tara, Soybean variety JS 335 and local sunhemp for green manuring were used. Next season *Bt* cotton hybrid Ajeet 155 was used. The yields of intercrop were converted into pigeonpea equivalent (PEY) on prevailing market prices. Sunhemp and weed biomass, leaf litter of both crop and root biomass from $m^{-2}$ were dried and dry biomass was calculated. Available biomass for in-*situ* recycling were studied for next season Bt cotton. Bulk density, pH, available nutrients in soil were analyzed at initial and after harvest of system and soil microbial biomass carbon was taken at flowering stage of crops as per standard procedure. Balanceof nutrients was calculated over initialcontent of available NPK in the soil.

## RESULTS AND DISCUSSION

### A. Rainfall

Rainfall and rainy days during experimentation was indicated the first and third season was better for growth and yield of intercrops and their biomass. However, fifth season was hampered due to less rainfall and rainy days. Whereas, *Bt* cotton was suffered during second and sixth season due to less rainfall and rainy days. Only fourth season was good for *Bt* cotton growth and yield (Table 1).

**B. Biomass production**

Total biomass of leaf litter of pigeonpea, soybean and dry biomass of sunhemp after uprooting at 45 days for green manuring and dry weed biomass after weeding and root biomass of both crop in tillage practices indicated that mean biomass for *in-situ* recycling was higher under minimum tillage than conventional tillage i.e. 4808 and 4386 kg ha$^{-1}$, respectively (Table 2). The mean total biomass of the intercropping from pigeonpea + sunhemp was highest ( 6195 kg ha$^{-1}$) where sunhemp was green manured and weed biomass was also more in pigeonpea after sunhemp green manuring. The slow growth of pigeonpea upto flowering stage favoured weeds as compared to other system. This biomass was available for *in-situ* recycling in the same season as well as next season. This biomass was used for integrated nutrient management practices with inorganic fertilizer and vermicomposting for next season Bt cotton.

**C. Pigeonpea equivalent yield (PEY)**

The tillage practices did not influenced the pigeonpea equivalent yield during first,third and fifth season as well as in pooled mean. Numerically higher values were recorded with conventional tillage. Results indicated that with minimum tillage also same level of yield could be achieved with intercropping of this crops. Pigeonpea equivalent yield (PEY) was significantly influenced with different intercropping system in individual as well as in pooled data. The highest mean PEY (1779 kg ha$^{-1}$) was obtained from pigeonpea + soybean (1:2). Similar results were noted by Paslawar *et al,* (1989) and Jagtap and Holkar (1995). PEY of pigeonpea + soybean 1:5 and pigeonpea +sunnhemp (1:2) was at par with each other.

**Table 1: Rainfall and Rainy days for six years**

| Year | Rainfall (mm) | Rainy Days |
|---|---|---|
| 2010-11 | 1006.5 | 46 |
| 2011-12 | 464.3 | 34 |
| 2012-13 | 684.1 | 50 |
| 2013-14 | 908 | 49 |
| 2014-15 | 593.1 | 29 |
| 2015-16 | 645 | 28 |

**Seed cotton Yield (SCY)**

The effect of tillage practices did not show significant effect on seed cotton yield but numerically higher values were observed in conventional tillage as compared to minimum tillage in first and third cycle of rotation. However, second rotation was significant in respect of SCY when good distribution of rainfall. As tillage practices helped in conservation of moisture,which improved the growth and yield of Bt cotton.

The pooled seed cotton yield (1304 kg ha$^{-1}$) was produced when pigeonpea + sunhemp (1:2) was grown in previous year.Crop residue recycling might have helped in moisture conservation and supplied continuous nutrient to cotton (Table 4).

**Table 2: MeanBiomass (leaf litter, root biomass and weeds) available for *in-situ* recycling from pigeonpea based cropping system**

| Treatments | Biomass available for in-situ recycling from intercropping (Kg ha$^{-1}$) | | | Mean |
|---|---|---|---|---|
| | First season | Third season | Fifth season | |
| **A) Tillage Practices** | | | | |
| Conventional Tillage | 3305 | 6089 | 3764 | 4386 |
| Minimum Tillage | 4330 | 6312 | 3782 | 4808 |
| **B) Cropping systems** | | | | |
| Pigeonpea + Soybean (1:2) | 4342 | 5261 | 4293 | 4632 |
| Pigeonpea + Sunhemp (1:2) | 6659 | 6801 | 5127 | 6195 |
| Pigeonpea + Soybean (1:5) | 4338 | 6733 | 4750 | 5273 |

**Table 3: Pigeonpea equivalent yield as influenced by tillage practices and intercropping system. (2010, 2012 & 2014)**

| Treatments | PigeonpeaEquivalent Yield (Kg ha $^{-1}$) | | | |
|---|---|---|---|---|
| | 2011-12 | 2013-14 | 2015-16 | Pooled |
| **A) Tillage Practices** | | | | |
| Conventional tillage | 1726 | 1956 | 793 | 1492 |
| Minimum tillage | 1654 | 1979 | 790 | 1474 |
| SE (m±) | 54 | 64 | 19 | 31 |
| CD at 5% | NS | NS | NS | NS |
| **B) Cropping System** | | | | |
| Pigeonpea +Soybean (1:2) | 1939 | 2447 | 951 | 1779 |
| Pigeonpea +Sunhemp (1:2 GM) at 45 DAS | 1434 | 1805 | 738 | 1326 |
| Pigeonpea +Soybean (1:5) | 1697 | 1650 | 686 | 1344 |
| SE (m) ± | 66 | 79 | 23 | 38 |
| CD at 5% | 200 | 239 | 70 | 116 |

Application of integrated nutrient sources at proper quantity which was significantly boosted the yield of cotton in individual year andin pooled data. The maximum seed cotton yield (1387 kg ha $^{-1}$) was recorded with 100 per cent RDF + shed biomass of previous cropping system followed by shed biomass + 50 per cent RDF + 50 per cent N through vermicomposting applied to *Bt* cotton. The seed cotton yield was increased by 22.2 per cent due to application of100 per cent RDF + shed biomass of previous cropping system over only shed biomass. Shed biomass of previous cropping system+ 100 per cent RDF might be provided the nutrient requirement of Bt cotton

**Table 4: Seed Cotton Yield (2011-12 , 2013-14 and 2015-16 ) as influenced by tillage practices, cropping system and integrated nutrient management to Bt cotton**

| Treatment | | | Seed Cotton Yield (Kg ha $^{-1}$) | | | |
|---|---|---|---|---|---|---|
| | | | 2011-12 | 2013-14 | 2015-16 | Pooled mean |
| **Main Plot A) Tillage Practices** | | | | | | |
| $T_1$ | - | Conventional tillage | 1193 | 1643 | 1132 | 1285 |
| $T_{2}$ | - | Minimum tillage | 1181 | 1577 | 1137 | 1266 |
| | | SE (m) ± | 6 | 23 | 19 | 6 |
| | | CD at 5% | NS | 74 | NS | NS |
| **B)Cropping System** | | | | | | |
| $C_1$ | - | Pigeonpea +Soybean (1:2) | 1183 | 1571 | 1109 | 1267 |
| $C_2$ | - | Pigeonpea +Sunhemp (1:2 GM) at 45 DAS | 1219 | 1635 | 1162 | 1304 |
| $C_3$ | - | Pigeonpea +Soybean (1:5) | 1159 | 1579 | 1133 | 1256 |
| | | SE (m) ± | 7 | 29 | 24 | 10 |
| | | CD at 5% | 23 | NS | NS | 33 |
| **Sub Plot – Nutrient management to cotton (2, 4, 6$^{th}$ season of second rotation)** | | | | | | |
| $N_1$ | - | Shed biomass of previous crop (Control) | 1078 | 1434 | 854 | 1135 |
| $N_2$ | - | Shed biomass+ 50 % VC from residue | 1155 | 1510 | 1173 | 1275 |
| $N_3$ | - | Shed biomass + 50 % RDF + 50 % N (VC) | 1228 | 1647 | 1223 | 1325 |
| $N_4$ | - | Shed biomass + RDF (60:30:30 NPK kg ha$^{-1}$) | 1288 | 1791 | 1299 | 1387 |
| | | SE (m) ± | 33 | 30 | 31 | 20 |
| | | CD at 5% | 96 | 87 | 91 | 59 |

and moisture supply during crop growth. Results are in conformity with the Bhalerao *et.al.* (2008).

**E. Physico-Chemical and biological properties**

Soil reaction, bulk density, organic carbon,soil microbial biomass C and available nitrogen, phosphorous and potassium were influenced after sixth year after Bt cotton over initial values (Table 5).

Due to addition of leaf litter,weeds and root biomass of all three crops in their respective cropping system the values of organic carbon, soil microbial biomass C and available nitrogen, phosphorous and potassium were higher over initial values and these values were higher with minimum tillage. Similarly, higher values were observed in pigeonpea + sunhemp (1:2) system. This might be due to addition of sunhemp as mulch as well as leaf litter of pigeonpea and weeds. More and Hangarge 2003 and He *et al.,* 2009 reported that pH reduced slightly with application of FYM, crop residues and green manures. The organic carbon content was also increased over initial values due to green manuring of sunhemp. Available NPK values were improved under pigeonpea + sunhemp (1:2) system. This might be due to *in-situ* addition of shed biomass in this system. Similar results were reported by Prasad and Singh1997 and Paslawar *et al.* (2007). SMBC was maximumat 90 days after sowing, when moisture was higher under minimum tillage and pigeonpea + sunhemp due to soil disturbances were less in minimum tillage.

Bulk density was slightly reduced under minimum tillage and in cropping system and INM practices. Organic carbon content, soil microbial biomass and NPK values of soil were increased after harvest of cotton crop (sixth season). The highest values of OC, SMBC and available NPK,when intercropping of pigeonpea + sunhemp (1:2) was grown in previous year. Whereas these values were improved under shed biomass + 50 per cent RDF + 50 per cent RDN through vermicomposting applied to *Bt* cotton. Similar results were observed by Katkar *et al,*( 2012 ) when combined use of FYM @10 tonne $ha^{-1}$ with 100 per cent NPK increased microbial biomass carbon.

## CONCLUSION

In conservation agriculture, bio-mulching of sunhemp at 45 DAS in Pigeonpea inter cropping (1:2) in first year followed by rotation system of Bt cotton under minimum tillage (1 Harrowing + 1 hoeing + herbicide) with 100 per cent RDF (60:30:30 NPK kg $ha^{-1}$) is recommended for higher returns from Bt cotton and enhancing soil health. Bio -mulching of sunhemp along with shedded biomass of pigeonpea saves application of compost.

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**Table 5: Bulk Density, organic carbon and NPK as influenced by different treatments after six years of season.**

| Treatments | | Bulk Density Mg $m^{-3}$ | Organic carbon (g $kg^{-1}$) | | Nitrogen (kg $ha^{-1}$) | | Phosphorous (kg $ha^{-1}$) | | Potassium (kg $ha^{-1}$) | | SMBC ($Kg ha^{-1}$) at (90DAS) | Soil (ug $g^{-1}$) carbon organic stock (0-15 cm depth) Mg ha-1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Initial | At harvest | Initial | At harvest | Initial | At harvest | Initial | At harvest | | |
| A) | **Main Plots-Tillage Practices** | | | | | | | | | | | |
| $T_1$ | Conventional tillage | 1.29 | 4.9 | 5.1 | 212 | 217 | 15.7 | 18.2 | 324 | 333 | 240 | 9.86 |
| $T_2$ | Minimum tillage | 1.27 | 5.0 | 5.2 | 213 | 219 | 15.7 | 18.5 | 323 | 335 | 261 | 9.90 |
| B) | **Cropping System** | | | | | | | | | | | |
| $C_1$ | Pigeonpea + Soybean (1:2) | 1.28 | 4.8 | 5.1 | 212 | 222 | 15.6 | 18.7 | 323 | 336 | 242 | 9.79 |
| $C_2$ | Pigeonpea +Sunhemp (1:2 GM) at 45 DAS | 4.9 | 5.4 | 212 | 226 | 15.7 | 19.3 | 324 | 339 | 265 | 10.28 | 1.27 |
| $C_3$ | Pigeonpea + Soybean (1:5) | 1.28 | 4.9 | 5.2 | 212 | 223 | 15.7 | 18.8 | 234 | 335 | 237 | 9.98 |
| C) | **Sub plots-Nutrient Management to Cotton (2nd Season)** | | | | | | | | | | | |
| $N_1$ | Shed biomass of 1previous crop | 1.28 | 4.9 | 5.1 | 212 | 218 | 15.5 | 17.7 | 322 | 331 | 238 | 9.79 |
| $N_2$ | Shed biomass + 50 % VC from residue | 1.27 | 4.9 | 5.4 | 212 | 225 | 15.8 | 20.5 | 323 | 334 | 261 | 10.28 |
| $N_3$ | Shed biomass + 50 % RDF + 50 % N (VC) | 1.27 | 4.9 | 5.5 | 213 | 227 | 15.8 | 21.7 | 325 | 335 | 251 | 10.47 |
| $N_4$ | Shed biomass + RDF (60:30:30) | 1.29 | 5.0 | 5.2 | 213 | 215 | 15.8 | 20.1 | 324 | 330 | 248 | 10.06 |

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# Safed Musli Yield and Micronutrient Status under Safed Musli + Pigeonpea Intercropping System

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**ABSTRACT**

The present investigation entitled was carried out at Nagarjun Medicinal Plants Garden, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) to find out the effect of safed musli and pigeonpea intercropping on safed musli yeidl and micronutrient status. The experiment was framed as Safed musli+ Pigeonpea intercropping with various row proportions T1 – Safed musli + Pigeonpea 2:1, T2 – Safed musli+ Pigeonpea 3:1, T3 – Safed musli + Pigeonpea 2:2 , T4 – Safed musli + Pigeonpea 1:2, T5 – Sole Safed musli, T6 – Sole Pigeonpea. The experiment was laid in Randomized Block Design with four replications and six treatments. In yield contributing characters of safed musli significantly highest no. of roots plant$^{-1}$, root length and root girth of safed musli was increased in treatment T2 i.e. safed musli + pigeonpea (3:1). Similarly fresh and dry root yield g plant-1 was significantly increased under treatment T2 i.e. safed musli + pigeonpea (3:1). The micronutrients status in soil was significantly increased under T4 i.e. safed musli + pigeonpea in 1:2 row proportion.

The main concept of intercropping is to increasing total productivity per unit area and time, as well as equitable and judicious utilization of land resources and inputs. One of the main reasons for getting higher yields from intercropping systems are mainly due to the component crops are able to use face natural resources than grown separately (Willey and Rao, 1979). A careful selection of crops having different growth habits can reduce the mutual competition to a considerable extent. Hence, choice of component crops in intercropping needs to be suitably maneuvered to harvest the synergism among them towards efficient utilization of resource base and to increase overall productivity (Mandal, *et. al.,* 1986).

*Chlorophytum borivilianum* is a perennial important herb known as 'Safed musli' which is a root crop belonging to the family Liliaceae. The roots of *Chlorophytum borivilianum* have great medicinal value due to saponin content and used extensively in Ayurvedic medicines and is well known tonic and aphrodisiac drug given to cure general debility.

Pigeonpea is an important legume food and drought tolerant crop and having potential to sustain productivity and profitability in drought prone areas. Being a legume, the residual nitrogen available to subsequent crop is estimated to around 40 kg ha$^{-1}$. Intercropping with Pigeonpea provides an opportunity to grow them together as they have different growth habits and maturity period. The Pigeonpea being deep rooted and comparatively slow growing in its early growth stage, during which the more rapidly growing crops like Safed musli can be conveniently intercropped to utilize natural resources more efficiently. The sole cropping of safed musli has a risk. The replacement of traditional crops with alternative crops like Safed musli may be unsustainable in large context and therefore, it is necessary to explore the possibilities of the growing these crops as an intercrop with the traditional crop in efficient cropping systems. In order to generate useful information for such type of potential areas, present investigation to study safed muli yield and micronutrient status under Safed musli + Pigeonpea intercropping under rainfed condition.

## MATERIAL AND METHODS

The field experiment was conducted at Nagarjun medicinal plant Garden Dr. PDKV Akola during kharif season 2015-2016 and 2016-2017. Experiment was laid out in Randomized Block Design with four replications and six treatments. The experimental soil order was inceptisol, the fertility status of soil was moderate in organic carbon, low in available nitrogen and available phosphorus and very high in available potassium while the soil

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micronutrient contents (Zn, Fe, Mn, Cu) were above the critical level. FYM @ 20 t ha$^{-1}$ was applied common for all treatments of Safed musli and for Pigeonpea: FYM @ equivalent to RDN (25 kg N ha$^{-1}$).

**Treatment details**

**$T_1$** Safed musli + Pigeonpea 2:1 row proportion

**$T_2$** Safed musli+ Pigeonpea 3:1 row proportion,

**$T_3$** Safed musli + Pigeonpea 2:2 row proportion

**$T_4$** Safed musli + Pigeonpea 1:2 row proportion,

**$T_5$** Sole Safed musli,

**$T_6$** Sole Pigeonpea.

## RESULTS AND DISCUSSION

**Yield contributing characters**

**Number of Roots**

The number of roots per plant was significantly influenced by the intercropping in both the year. Number of roots of safed musli were ranged from 7.75 to 9.25 plant$^{-1}$ and 7.80 to 10.20 roots plant$^{-1}$ during 2015-16 and 2016-17, respectively (Table 1). Further, the highest no of roots of safed musli (9.25 plant$^{-1}$) was recorded with safed musli + pigeonpea in 3:1 row proportion ($T_2$) which was at par with treatments $T_3$ (2:2 row proportion) and $T_5$ (sole safed musli) during first year. However, during second year (2016-17) data showed that highest number of roots (10.20 plant$^{-1}$) was recorded under safed musli + pigeonpea in 3:1 row proportion which was at par with treatment $T_5$ (sole safed musli).

Pooled data indicated that the application of safed musli+ pigeonpea in 3:1 row proportion ($T_2$) recorded significantly highest number of roots (9.70 plant$^{-1}$) followed by sole safed musli ($T_5$).

**Root Length**

The root length was significantly influenced by the intercropping in both the years. Root length varied from 6.35 to 7.00 cm and 6.39 to 7.24 cm during 2015-16 and 2016-17 respectively. Further, it was noticed that highest root length of safed musli (7.00 cm) was recorded under safed musli + pigeonpea in 3:1 row proportion ($T_2$) which was at par with $T_3$ (2:2 row proportion) and $T_4$ (1:2 row proportion) during first year. However, during second year (2016-17) data showed that highest root length (7.24 cm) was recorded under safed musli + pigeonpea in 3:1 row proportion ($T_2$) while lowest (6.39 cm) root length was observed in treatment under safed musli + pigeonpea in 2:2 row proportion ($T_3$).

The pooled data also indicated that the root length was significantly highest (7.12 cm) with treatment $T_2$ (3:1 row proportion) as compared to $T_1$ (2:1 row propotion), $T_3$ (2:2 row proportion) and $T_5$ (sole safed musli), however, at par with $T_4$ (1:2 row proportion).

**Root Girth**

Root girth varied from 5.38 to 6.10 mm and 5.44 to 6.05 mm during 2015-16 and 2016-17, respectively and the highest root girth of safed musli (6.10 mm) was recorded under sole safed musli ($T_5$) which was at par with treatment $T_1$ (2:1 row proportion), $T_2$ (3:1 row proportion) and $T_4$ (1:2 row proportion) during first year study except $T_3$ (2:2 row proportion). During second year and in pooled data the

**Table 1. Number of roots, root length and root girth of safed musli as influenced by safed musli + pigeonpea intercropping system**

| Treatments | No. of Roots plant$^{-1}$ | | | Root Length (cm) | | | Root Girth (mm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2015-16 | 2016-17 | Pooled | 2015-16 | 2016-17 | Pooled | 2015-16 | 2016-17 | Pooled |
| $T_1$ - Safed musli + Pigeonpea (2:1) | 8.03 | 8.53 | 8.28 | 6.35 | 6.65 | 6.50 | 5.48 | 5.60 | 5.54 |
| $T_2$ - Safed musli + Pigeonpea (3:1) | 9.25 | 10.20 | 9.70 | 7.00 | 7.24 | 7.12 | 5.95 | 6.05 | 6.00 |
| $T_3$ - Safed musli + Pigeonpea (2:2) | 8.30 | 8.50 | 8.25 | 6.61 | 6.39 | 6.50 | 5.38 | 5.44 | 5.41 |
| $T_4$ - Safed musli + Pigeonpea (1:2) | 7.75 | 7.80 | 7.78 | 6.59 | 6.68 | 6.63 | 5.66 | 5.59 | 5.63 |
| $T_5$ - Sole Safed musli | 8.75 | 9.00 | 8.87 | 6.41 | 6.60 | 6.50 | 6.10 | 5.85 | 5.97 |
| $T_6$ - Sole Pigeonpea | - | - | - | - | - | - | - | - | - |
| SE (m) ± | 0.39 | 0.41 | 0.31 | 0.29 | 0.30 | 0.20 | 0.24 | 0.26 | 0.17 |
| CD at 5 % | 1.14 | 1.20 | 0.93 | 0.50 | 0.75 | 0.59 | 0.63 | 0.48 | 0.51 |

highest root girth was also recorded under safed musli + pigeonpea in 3:1 row proportion ($T_2$) which was also at par with treatments $T_5$ (sole safed musli) and $T_1$ (2:1 row proportion).

As the safed musli is partial shade loving plant the intercropping with pigeonpea might have beneficial effect on safed musli crop growth which ultimately recorded in improvement of yield contributing characters. These results are in confirmiy of findings of studies on safed musli + Pigeonpea intercropping conducted at Akola (Anonymous, 2015 and Shivankar, 2015).

**Safed musli fresh root yield**

The fresh root yield (Table 2) significantly influenced by different intercropping proportions and the higher fresh root yield (33.40 q ha$^{-1}$) was obtained with the intercropping of safed musli + pigeonpea intercropping in 3:1 row proportion which was at par with treatment $T_5$ (sole safed musli). While, the lowest fresh root yield (13.31 q ha$^{-1}$) was recorded with of safed musli + pigeonpea in 1:2 proportion ($T_4$).

During second year and in pooled data also the highest fresh root yield was recorded in $T_2$ (safed musli + pigeonpea in 3:1 row proportion) which was at par with $T_5$ (sole safed musli). Whereas, lowest fresh root yield (12.38 q ha$^{-1}$) was recorded in treatment $T_4$ *i.e.,* safed musli + pigeonpea in 1:2 proportion.

**Safed musli dry root yield**

The dry root yield was significantly influenced by intercropping with various row propotion of safed musli + pigeonpea and it was significantly higher (5.67 q ha$^{-1}$) under treatment $T_2$ *i.e.,* in 3:1 row proportion. In second year, significantly highest dry yield (5.17 q ha$^{-1}$) was recorded in $T_2$ *i.e.,* safed musli + pigeonpea in 3:1 row proportion. While, lowest (2.26 q ha$^{-1}$) dry yield per hector was recorded in treatment $T_4$ under 1:2 row proportion. Pooled data also indicated that significantly higher dry yield (5.42 q ha$^{-1}$) was recorded with treatment $T_2$ followed by treatment $T_5$ (5.30 q ha$^{-1}$).

Significantly highest root yield obtained with the intercropping of safed musli + pigeon pea in 3:1 row might be due to favorable partial shade effect which recorded in better crop growth and ultimately the root yield. These results are in accordance with the findings of Shivankar (2019).

**Available micronutrients after harvest**

**Available Iron**

The data in respect of DTPA extractable iron as influenced by various treatments is presented in Table 3. The availability of iron content in soil differs among various treatments and it was varied from 4.84 to 4.96 mg kg$^{-1}$ and 4.90 to 5.00 mg kg$^{-1}$ after harvest of safed musli and pigeonpea grown in year 2015-16 and 2016-17 respectively.

Further, it was observed that the available iron was significantly highest (4.96 mg kg$^{-1}$) in treatment $T_4$ *i.e.,* safed musli + pigeonpea in 1:2 row proportion during 1st year which was at par with rest of treatments except T6 *i.e.,* sole pigeonpea. Similar results were also observed during second year of study.

The enhancement in available iron may be due to addition of organic manure which contain appreciable quantity of iron and due to the ability of organic substances to form stable water soluble complexes preventing the reaction of soil constituents and also increasing the Fe content through release from the native sources. The results are in agreement with Lohakare (1980), Prakash *et al.* (2002) and Naguib (2011).

**Available Manganese**

The availability of manganese content in soil after harvest of safed musli was differs among various treatments and it was varied from 2.82 to 2.95 mg kg$^{-1}$ and 2.83 to 2.98 mg kg$^{-1}$ in year 2015-16 and 2016-17 respectively.

Further, it was observed that the available manganese was significantly highest (2.95 mg kg$^{-1}$) with the safed musli + pigeonpea in 1:2 row proportion ($T_4$) which was at par with treatment $T_2$ (3:1 row proportion). However, during 2$^{nd}$ year data indicated that available manganese was significantly highest (2.98 mg kg$^{-1}$) under safed musli + pigeonpea in 1:2 row proportion ($T_4$) which was at par under 3:1 row proportion ($T_2$).

**Table 2. Fresh and Dry root yield of safed musli as influenced by safed musli + pigeonpea intercropping system**

| Treatments | Safed musli fresh root yield (q ha$^{-1}$) | | | Safed musli dry root yield (q ha$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2015-16 | 2016-17 | Pooled | 2015-16 | 2016-17 | Pooled |
| $T_1$ - Safed musli + Pigeonpea (2:1) | 24.43 | 22.54 | 23.48 | 4.15 | 3.84 | 3.99 |
| $T_2$ - Safed musli + Pigeonpea (3:1) | 33.4 | 30.44 | 31.92 | 5.67 | 5.17 | 5.42 |
| $T_3$ - Safed musli + Pigeonpea (2:2) | 22.55 | 21.6 | 22.07 | 3.83 | 3.67 | 3.75 |
| $T_4$ - Safed musli + Pigeonpea (1:2) | 13.31 | 12.38 | 12.84 | 2.26 | 2.1 | 2.18 |
| $T_5$ - Sole Safed musli | 32.14 | 30.22 | 31.18 | 5.46 | 5.13 | 5.3 |
| $T_6$ - Sole Pigeonpea | - | - | - | - | - | - |
| SE (m) ± | 0.68 | 0.72 | 0.46 | 0.07 | 0.09 | 0.006 |
| CD at 5 % | 2 | 2.1 | 1.4 | 0.23 | 0.3 | 5.4 |

**Available Zinc**

The availability of zinc content in soil after harvest of safed musli was varied from 0.64 to 0. 66 mg kg$^{-1}$ and 0.65 to 0.67 mg kg$^{-1}$ in year 2015-16 and 2016-17 respectively. Further, it was observed that the available zinc was significantly highest (0.66 mg kg$^{-1}$) with the safed musli + pigeonpea in 1:2 row proportion ($T_4$) during 1st year. However, during 2$^{nd}$ year available zinc was highest (0.67 mg kg$^{-1}$) withall the treatments except $T_3$, and $T_6$ also

**Available Copper**

The availability of copper content in soil after harvest of safed musli was differs among various treatments and it was varied from 2.30 to 2.34 mg kg$^{-1}$ and 2.31 to 2.35 mg kg$^{-1}$ in year 2015-16 and 2016-17, respectively. The available copper was significantly highest (2.34 mg kg$^{-1}$) under the safed musli + pigeonpea in 1:2 row proportion ($T_4$) which was at par with safed musli + pigeonpea in 2:1 row proportion ($T_1$) and safed musli + pigeonpea in 3:1 row proportion (T2) during 1$^{st}$ year. Whereas, during 2$^{nd}$ year data indicated that available copper was significantly highest (2.35 mg kg$^{-1}$) under safed musli + pigeonpea in 1:2 row proportion ($T_2$) which was at par with safed musli + pigeonpea in 3:1 row proportion.

The possible reason for increased micronutrient status could be and enhanced microbial activity in the soil and consequent release of complex organic substances which acts as (chelating agents), which could have prevented micronutrient precipitation, fixation, oxidation and leaching. The results are line with Bellaki *et al.* (1998) and Guled *et al.* (2002). Available status of iron, manganese, zinc and copper (mg kg$^{-1}$) (Table 3) after 2 cycles of experimentation revealed that there was with all the intercropping treatments and except sole crop pigeon pea.

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**Table 3. Effect of safed musli + pigeonpea intercropping on available iron, manganese, zinc and copper after harvest.**

| Treatments | Available iron (mg kg$^{-1}$) | | Available manganese (mg kg$^{-1}$) | | Available Zinc (mg kg$^{-1}$) | | Available Copper (mg kg$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|
| | 2015-16 | 2016-17 | 2015-16 | 2016-17 | 2015-16 | 2016-17 | 2015-16 | 2016-17 |
| $T_1$ - Safed musli + Pigeonpea (2:1) | 4.92 | 4.96 | 2.85 | 2.88 | 0.65 | 0.67 | 2.32 | 2.32 |
| $T_2$ - Safed musli + Pigeonpea (3:1) | 4.91 | 4.95 | 2.91 | 2.92 | 0.65 | 0.67 | 2.33 | 2.34 |
| $T_3$ - Safed musli + Pigeonpea (2:2) | 4.91 | 4.97 | 2.84 | 2.9 | 0.65 | 0.66 | 2.31 | 2.32 |
| $T_4$ - Safed musli + Pigeonpea (1:2) | 4.96 | 5.00 | 2.95 | 2.98 | 0.66 | 0.67 | 2.34 | 2.35 |
| $T_5$ - Sole Safed musli | 4.9 | 4.96 | 2.84 | 2.9 | 0.65 | 0.67 | 2.31 | 2.32 |
| $T_6$ - Sole Pigeonpea | 4.84 | 4.9 | 2.82 | 2.83 | 0.64 | 0.65 | 2.3 | 2.31 |
| initial | 4.80 | - | 2.8 | - | 0.65 | 2.3 | - | |
| SE (m) ± | 0.02 | 0.02 | 0.03 | 0.02 | 0.002 | 0.003 | - | 0.01 |
| CD at 5% | 0.06 | 0.05 | 0.08 | 0.07 | 0.005 | 0.008 | 0.03 | 0.003 |

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# Influence of Fumigants and Exposure Period on Seed Quality and Storability of Groundnut

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## ABSTRACT

The present study was conducted during 2014-2015 at the laboratory of Seed Technology Research Unit, Dr. PDKV, Akola to find out ideal fumigant with proper exposure period to control groundnut beetle and maintenance of seed quality of groundnut. The results revealed that groundnut seed pods fumigated with both the fumigants (Aluminium phosphoid and Ethylene dibromide) retained satisfactory germination of 70 per cent (MSCS) up to four months of storage period. Among the exposure period, groundnut seeds fumigated with an exposure period up to 96 hours maintained the germination per cent above minimum seed certification standard (70 %) up to six months whereas, groundnut seeds fumigated with an exposure periods beyond 96 hours, could retain 70 per cent germination upto two months only. In interaction of fumigants and exposure period, groundnut seeds fumigated with ethylene dibromide for 24 hours exposure period ($F_2P_1$) was found to be superior by recording highest germination (64.00 %), speed of germination (26.82) seedling length (11.60 cm) and seedlings vigour index (743) at the end of experiment. Besides, this treatment also recorded lower electrical conductivity of seed leachate (0.820 $dSm^{-1}$) and less per cent reduction germination (31.91 %) and beetle population (3.21) at the end of tenth months of storage.

Groundnut (*Arachis hypogaea* L.) is the king of oil seed crops containing 48 -50 per cent edible oil and 25 per cent high quality protein and being a legume it occupies a unique position in the farming system. It is the world's six most important source of edible oil and third most important source of vegetable protein (Nigam, 2014).

Over 60 per cent of the global production is crushed for extraction of oil for edible and industrial uses, while 40 per cent is consumed for food and other uses (seed for sowing) (Birthal *et al*., 2010). For seed purpose the pods are to be stored for longer period during which it is prone to various insect particularly bruchids which causes greater losses.

During storage, quality of groundnut seed gets deteriorated due to several reasons, out of which, storage pest infestation contributes its major share. The loss in seed quality may be quantitative or qualitative or both. Damage by *Caryedon serratus* (Olivier) in groundnut seeds to the extent of 45 per cent results in 65 per cent loss in dry weight of damaged seeds (Kapadia, 1994). The qualitative loss of seed can be attributed to biochemical changes in protein, carbohydrates, fatty acids and vitamins (Girish *et al*., 1972).

During storage, quality of seed can be maintained for a longer period by adopting several prophylactic measures viz., disinfestation of storage room, physical and chemical treatments, fumigation, etc. Among these methods, fumigation is said to be a convenient, rapid and effective method to control infestation of store pests. For fumigation, many chemicals are in use to achieve the desired results. Aluminum phosphide is one of the most toxic fumigant used to kill stored grain pests like insects, mites and rodents. Despite its harmful effect, aluminum phosphide, being highly inflammable is a safe and convenient fumigant. Ethylene dibromide (EDB) has high boiling point and its vapours are non-inflammable and is absorbed by many materials, but does not penetrate well. Ethylene dibromide does not normally react with constituents of foodstuff. The seed quality changes during storage, the quality parameters such as germination and vigour index decreased from 84-79 per cent and 2581-2005, respectively while moisture contents increased from 7.1 to 8per cent (Junaithal Begum *et al.,* 2013).

A thorough knowledge of these factors is very much required for successful fumigation process with a given gas. Hence, in the present study an attempt has

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been made to find out ideal fumigant with proper exposure period to control bruchids and maintenance of seed quality parameters of groundnut.

## MATERIAL AND METHODS

The present investigation entitled "Influence of fumigation on seed quality during storage of groundnut (*Arachis hypogaea* L.)" was conducted during 2014-2015 at the laboratory of Seed Technology Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The variety TAG-24 was selected for seed treatment of groundnut.

The experiment consisted of 16 treatment combinations involving two fumigants (F) viz., Aluminium phosphide (0.9 g $q^{-1}$) and Ethylene dibromide (3 ml $q^{-1}$) (Ranga Rao et al. 2010). The calculated quantities of fumigants were placed in the plastic tins measuring 30 cm (length) 30 cm (breadth) and 44 cm (height) containing pods and the boxes were closed with lids. The cover portion of lid was made air tight by plastering with celephine tape. After the required exposure period, the cover was opened and pods were removed from boxes and were stored in aerated gunny bags under ambient storage conditions. This process of fumigation was repeated as per the treatment combinations for effecting repeated fumigation of the pods. Exposure period viz., no fumigation (control), 24, 48, 72, 96, 120, 144 and 168 hours exposure period were followed. The seed quality parameters like germination percentage, speed of germination, seedling length, seedling vigour index, per cent reduction in germination, electrical conductivity and beetle population were recorded bimonthly. The germination test was conducted as per ISTA rules (Anon., 1999), SVI as per Abdul- Baki and Anderson (1973) and speed of germination using the formula suggested by Maguire (1962). The data were statistically analysed for completely randomized design with factorial concept with three replications (Panse and Sukhatme, 1978).

## RESULTS AND DISCUSSION

The result revealed that germination percentage, speed of germination, seedling length, seedling vigour index and electrical conductivity differed significantly among the exposure periods, irrespective of fumigants in all the months of storage. The result revealed that, the seeds fumigated with EDB recorded higher seed quality parameters namely the germination percentage (55.92 per cent), speed of germination (20.23), seedlng length (9.72 cm), seedling vigour index (547), and lower electrical conductivity of seed lachates (1.085 $dSm^{-1}$), less percent reduction in germination (40.51 %) than the seeds fumigated with Aluminium phosphide at the end of tenth month of storage. This clearly indicated that ethylene dibromide has less deleterious effect on seed quality compared to Aluminium phosphide since, it is being highly inflammable penetrates more in to the seed and having more residual effect on fumigated seeds than EDB. Similar results were reported by Lindgren et al (1962). The fumigants retained in the seed might have caused adverse effect on chemical balance of the seed (Harrington and Douglas, 1970).

The seed fumigated with Aluminium phosphide noticed less (3.21) number of groundnut beetle population compared to EDB (4.33) at the end of ten month of storage indicating the toxicity of respective fumigant but affected the seed quality parameters adversely. Aluminium phosphide could maintained the satisfactory germination (70 %) up to four months with less pest population. Similar results were reported by Kamble *et al.,* (2013) and Lindgren *et al.,* (1962). The seed quality parameters declined with the increase in exposure period from 24 hours to 168 hours in all the months of storage and more prominent after 96 hours of exposure period and discussed here parameter wise.

### Germination percentage (per cent)

Germination percentage differed significantly among the exposure periods, irrespective of fumigants in all the months of storage. While, the seeds exposed to 168 hours exposure period recorded significantly lesser (79.67, 69.83, 60.83, 59.00 and 49.84 %) germination during second, fourth, sixth, eighth and tenth month of storage period respectively (Table 1). The seeds fumigated with an exposure period up to 96 hours maintained the germination per cent above the minimum seed certification standard (70 %) up to six months of storage. Whereas, beyond 96 hours could retain 70 per cent germination up to four months only.

**Table 1. Influence of fumigants and exposure periods on germination percentage of groundnut seeds.**

| Treatment | Months after storage | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Two | | | Four | | | Six | | | Eight | | | Ten | | |
| | F1 | F2 | Mean | F1 | F2 | Mean | F1 | F2 | Mean | F1 | F2 | Mean | F1 | F2 | Mean |
| P0 | 83.67 | 84.00 | 83.84 | 75.67 | 76.33 | 76.00 | 70.33 | 71.33 | 70.83 | 65.67 | 67.33 | 66.50 | 55.67 | 56.67 | 56.17 |
| | (66.16) | (66.43) | (66.30) | (60.44) | (60.89) | (60.67) | (57.00) | (57.63) | (57.31) | (54.13) | (55.14) | (54.64) | (48.25) | (48.83) | (48.54) |
| P1 | 83.00 | 89.00 | 86.00 | 74.00 | 88.00 | 81.00 | 69.67 | 77.67 | 73.67 | 65.33 | 71.67 | 68.50 | 55.33 | 64.00 | 59.67 |
| | (65.66) | (70.64) | (68.15) | (59.35) | (69.74) | (64.54) | (56.58) | (61.80) | (59.19) | (53.93) | (57.84) | (55.89) | (48.06) | (53.13) | (50.60) |
| P2 | 84.00 | 84.67 | 84.34 | 79.67 | 80.00 | 79.84 | 72.00 | 75.00 | 73.50 | 66.00 | 67.67 | 66.84 | 58.33 | 58.67 | 58.50 |
| | (66.43) | (66.95) | (66.69) | (63.20) | (63.44) | (63.32) | (58.05) | (60.00) | (59.03) | (54.33) | (55.35) | (54.84) | (49.80) | (49.99) | (49.89) |
| P3 | 86.33 | 83.67 | 85.00 | 84.00 | 77.33 | 80.67 | 75.00 | 71.33 | 73.17 | 69.33 | 66.00 | 67.67 | 59.67 | 57.00 | 58.34 |
| | (68.31) | (66.17) | (67.24) | (66.43) | (61.57) | (64.00) | (60.00) | (57.63) | (58.82) | (56.37) | (54.33) | (55.35) | (50.57) | (49.02) | (49.80) |
| P4 | 84.00 | 83.00 | 83.50 | 81.33 | 73.67 | 77.50 | 73.00 | 68.00 | 70.50 | 67.67 | 61.33 | 64.50 | 58.67 | 54.00 | 56.34 |
| | (66.43) | (65.66) | (66.04) | (64.40) | (59.13) | (61.77) | (58.70) | (55.55) | (57.12) | (55.35) | (51.55) | (53.45) | (49.99) | (47.29) | (48.64) |
| P5 | 84.00 | 81.67 | 82.84 | 71.00 | 71.33 | 71.17 | 66.33 | 69.67 | 68.00 | 60.33 | 62.67 | 61.50 | 51.33 | 53.67 | 52.50 |
| | (66.43) | (64.66) | (65.54) | (57.42) | (57.63) | (57.52) | (54.53) | (56.58) | (55.56) | (50.96) | (52.34) | (51.65) | (45.76) | (47.10) | (46.43) |
| P6 | 82.00 | 81.00 | 81.50 | 70.33 | 70.67 | 70.50 | 62.00 | 62.67 | 62.34 | 59.67 | 61.00 | 60.34 | 51.00 | 53.33 | 52.17 |
| | (64.90) | (64.16) | (64.53) | (57.00) | (57.21) | (57.10) | (51.94) | (52.34) | (52.14) | (50.57) | (51.36) | (50.96) | (45.57) | (46.91) | (46.24) |
| P7 | 79.33 | 80.00 | 79.67 | 70.33 | 69.33 | 69.83 | 61.33 | 60.33 | 60.83 | 57.33 | 60.67 | 59.00 | 49.67 | 50.00 | 49.84 |
| | (62.97) | (63.44) | (63.20) | (57.00) | (56.37) | (56.69) | (51.55) | (50.96) | (51.26) | (49.22) | (51.16) | (50.19) | (44.81) | (45.00) | (44.90) |
| Mean | **83.29** | **83.38** | **83.33** | **75.79** | **75.83** | **75.81** | **68.71** | **69.50** | **69.10** | **63.92** | **64.79** | **64.35** | **54.96** | **55.92** | **55.44** |
| | **(65.91)** | **(66.01)** | **(65.96)** | **(60.65)** | **(60.75)** | **(60.70)** | **(56.05)** | **(56.56)** | **(56.30)** | **(53.11)** | **(53.63)** | **(53.37)** | **(47.85)** | **(48.41)** | **(48.13)** |

| For comparing means of | SE(m)± | CD at 5 % | SE(m)± | CD at 5 % | SE(m)± | CD at 5 % | SE(m)± | CD at 5 % | SE(m)± | CD at 5 % |
|---|---|---|---|---|---|---|---|---|---|---|
| F | 0.16 | NS | 0.12 | NS | 0.11 | 0.33 | 0.09 | 0.27 | 0.09 | 0.26 |
| P | 0.31 | 0.90 | 0.23 | 0.67 | 0.23 | 0.66 | 0.19 | 0.54 | 0.18 | 0.53 |
| F x P | 0.44 | 1.28 | 0.33 | 0.94 | 0.32 | 0.93 | 0.26 | 0.76 | 0.26 | 0.75 |

*Figures in the parenthesis indicates arc sine transformed values

**NS** : Non significant

**Fumigant (F)Exposure periods (P)**

$F_1$ : Aluminium phosphide

$F_2$ : Ethylene dibromide

$P_2$ : 48 hours exposure period

$P_3$ : 72 hours exposure period

$P_0$ : No fumigation

$P_1$ : 24 hours exposure period

$P_6$ : 144 hours exposure period

$P_7$ : 168 hours exposure period

$P_4$ : 96 hours exposure period

$P_5$ : 120 hours exposure period

**Table 2. Influence of fumigants and exposure periods on speed of germination of groundnut seeds**

| Treatments | Months after storage | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Two | | | Four | | | Six | | | Eight | | | Ten | | |
| | **F1** | **F2** | **Mean** | **F1** | **F2** | **Mean** | **F1** | **F2** | **Mean** | **F1** | **F2** | **Mean** | **F1** | **F2** | **Mean** |
| P0 | 24.53 | 24.08 | 24.31 | 24.76 | 24.46 | 24.61 | 23.90 | 23.17 | 23.54 | 23.00 | 23.10 | 23.05 | 20.10 | 20.00 | 20.05 |
| P1 | 24.00 | 29.52 | 26.76 | 24.66 | 28.51 | 26.58 | 26.40 | 26.90 | 26.65 | 22.90 | 26.70 | 24.80 | 19.35 | 26.82 | 23.09 |
| P2 | 24.70 | 26.73 | 25.71 | 25.60 | 26.75 | 26.18 | 25.22 | 24.88 | 25.05 | 23.11 | 24.10 | 23.60 | 21.75 | 21.16 | 21.46 |
| P3 | 27.00 | 24.30 | 25.65 | 27.00 | 25.00 | 26.00 | 23.68 | 23.94 | 23.81 | 24.20 | 23.14 | 23.67 | 23.80 | 20.82 | 22.31 |
| P4 | 25.80 | 23.93 | 24.87 | 27.10 | 24.10 | 25.60 | 24.30 | 23.07 | 23.68 | 24.05 | 22.82 | 23.44 | 22.84 | 19.08 | 20.96 |
| P5 | 22.80 | 23.10 | 22.95 | 22.52 | 22.70 | 22.61 | 22.12 | 22.65 | 22.38 | 21.80 | 21.91 | 21.86 | 18.00 | 18.80 | 18.40 |
| P6 | 20.89 | 22.00 | 21.45 | 22.08 | 22.33 | 22.21 | 21.07 | 21.35 | 21.21 | 21.00 | 21.11 | 21.05 | 17.41 | 17.75 | 17.58 |
| P7 | 20.72 | 21.21 | 20.97 | 21.13 | 21.86 | 21.50 | 20.00 | 20.16 | 20.08 | 19.50 | 19.70 | 19.60 | 17.15 | 17.40 | 17.27 |
| **Mean** | **23.81** | **24.36** | **24.08** | **24.36** | **24.46** | **24.41** | **23.34** | **23.26** | **23.30** | **22.45** | **22.82** | **22.63** | **20.05** | **20.23** | **20.14** |
| For comparing means of | SE(M)± | CD at 5% | | SE(m)± | CD at 5% | | SE(m)± | CD at 5% | | SE(m)± | CD at 5% | | SE(m)± | CD at 5% | |
| F | 0.16 | 0.47 | | 0.15 | NS | | 0.16 | NS | | 0.15 | NS | | 0.15 | NS | |
| P | 0.33 | 0.95 | | 0.30 | 0.87 | | 0.32 | 0.91 | | 0.31 | 0.89 | | 0.30 | 0.87 | |
| F x P | 0.46 | 1.34 | | 0.43 | 1.23 | | 0.45 | NS | | 0.44 | 1.25 | | 0.43 | 1.24 | |

In interaction between fumigants and exposure periods, the treatment combination involving fumigation of seeds with ethylene dibromide for 24 hours exposure period ($F_2P_1$) recorded significantly higher per cent germination of (89.00, 88.00, 77.67, 71.67 and 64.00 %). While, it was lowest (79.33, 70.33, 61.33, 57.33 and 49.67%) in seeds fumigated with aluminium phosphide for 168 hours exposure period ($F_1P_7$) at the end of two, four, six, eight and ten months of storage respectively. Results of similar nature were reported by Alam, *et.al.* (2014) and Kamble, *et al.* (2013).

**Speed of germination**

The seed pods fumigated with EDB recorded numerically higher speed of germination of (24.36), While it was lower (23.81) in Aluminium phosphide fumigated seeds at the end of two months of storage respectively. During fourth, sixth, eighth and tenth month non-significant difference on germination were noticed due to fumigants (Table 2). The seeds fumigated for 24 hours exposure period recorded significantly highest speed of germination of (26.76, 26.58, 26.65, 24.80 and 23.09). While, it was lowest in 168 hours exposure period at second, fourth, sixth, eighth and tenth month of storage.

The interaction effect between fumigants and exposure periods noticed significant differences for speed of germination throughout storage period. The (Aluminium Phosphide for 24 hours exposure period) F2P1 treatment recorded significantly highest (29.52, 28.51, 26.90, 26.70 and 26.82) while $F_1P_7$ recorded lowest (20.72, 21.13, 20.00, 19.50 and 17.15) speed of germination during two, four, six, eight and ten months of storage respectively. Results of similar nature were reported by Vasudevan *et al.* (2014), Alam et.al. (2014) and Kamble *et al.* (2013).

**Seedling length**

The seeds fumigated with EDB recorded numerically higher seedling length of (12.29 cm), While it was lower (11.85 cm) in Aluminium phosphide fumigated seeds at the end of six months of storage, respectively. During second, fourth, eighth and tenth month non-significant differences on germination of seed were noticed due to fumigants. The seeds exposed to 24 hours fumigation recorded significantly higher seedling length of (14.30, 13.80, 13.25, 12.07 and 10.98 cm) followed by 48, 72 and 96 hours exposure periods. While, 168 hours exposure period of fumigation recorded lowest seedling length in all the month of storage (Table 3). Similar results were reported by Vasudevan et al. (2014) and Kamble *et al.* (2013).

In interaction effect between fumigants and exposure periods, the treatment $F_2P_1$ recorded significantly highest (16.08, 15.10, 14.09, 12.96 and 11.60 cm) seedling length, while it was lowest (11.21, 10.60, 10.20, 9.30 and 8.10 cm) in F1P7 treatment combination during two, four, six and eight months of storage respectively.

**Seedling vigour index**

The EDB fumigated seeds recorded significantly higher (1107, 859 and 547) seedling vigour indices. While, lower indices of (1070, 819 and 525) were recorded with aluminium phosphide at the end of two, six and ten months of storage, respectively. During fourth and eight months non-significant differences were noticed between the fumigants (Table 4).

Significantly higher vigour indices values were recorded in seeds fumigated for 24 hours exposure period (P1) followed by 48 hours exposure period throughout the storage period. Statistically, higher vigour indices values of (1235, 1127, 979, 829 and 657) were recorded in seeds exposed to fumigation for 24 hours exposure period (P1) while the 168 hours exposure period (P7) registered significantly lower indices values of (898, 757, 648, 551 and 407) during two, four, six, eight and ten months of storage, respectively. Results of similar nature were reported by Vasudevan et al. (2014) and Kamble *et al.* (2013).

In the interaction between fumigants and exposure periods, treatment combination $F_2P_1$ recorded significantly higher (1431, 1329, 1094, 929 and 743) vigour indices, while $F_1P_7$ treatment recorded lower indices values of (889, 746, 625, 533 and 402) at the end of second, fourth, sixth, eighth and tenth month of storage, respectively.

**Electrical conductivity of seed leachate**

Irrespective of the exposure periods, non-significant difference were recorded. The fumigant EDB

**Table 3. Influence of fumigants and exposure periods on seedling length (cm) of groundnut seeds**

| Treatments | Months after storage | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Two | | | Four | | | Six | | | Eight | | | Ten | | |
| | **F1** | **F2** | **Mean** | **F1** | **F2** | **Mean** | **F1** | **F2** | **Mean** | **F1** | **F2** | **Mean** | **F1** | **F2** | **Mean** |
| P0 | 13.10 | 13.25 | 13.17 | 12.84 | 12.90 | 12.87 | 12.20 | 12.25 | 12.23 | 11.20 | 11.25 | 11.23 | 9.11 | 9.35 | 9.23 |
| P1 | 12.52 | 16.08 | 14.30 | 12.50 | 15.10 | 13.80 | 12.41 | 14.09 | 13.25 | 11.17 | 12.96 | 12.07 | 10.35 | 11.60 | 10.98 |
| P2 | 13.10 | 15.11 | 14.10 | 13.00 | 14.11 | 13.55 | 12.68 | 13.50 | 13.09 | 11.40 | 12.60 | 12.00 | 10.40 | 11.20 | 10.80 |
| P3 | 14.80 | 13.09 | 13.94 | 14.10 | 13.13 | 13.62 | 13.50 | 12.54 | 13.02 | 12.46 | 11.30 | 11.88 | 10.00 | 10.20 | 10.10 |
| P4 | 14.10 | 12.51 | 13.31 | 13.30 | 12.70 | 13.00 | 12.73 | 11.80 | 12.26 | 11.80 | 10.70 | 11.25 | 10.80 | 9.15 | 9.98 |
| P5 | 12.28 | 12.39 | 12.34 | 11.80 | 11.90 | 11.85 | 10.75 | 11.60 | 11.18 | 9.60 | 10.50 | 10.05 | 8.70 | 9.20 | 8.95 |
| P6 | 11.50 | 12.07 | 11.79 | 10.70 | 11.30 | 11.00 | 10.30 | 11.41 | 10.85 | 9.50 | 9.65 | 9.58 | 8.60 | 8.80 | 8.70 |
| P7 | 11.21 | 11.35 | 11.28 | 10.60 | 11.10 | 10.85 | 10.20 | 11.11 | 10.66 | 9.30 | 9.36 | 9.33 | 8.10 | 8.22 | 8.16 |
| **Mean** | **12.83** | **13.23** | **13.03** | **12.36** | **12.78** | **12.57** | **11.85** | **12.29** | **12.07** | **10.80** | **11.04** | **10.92** | **9.51** | **9.72** | **9.61** |
| For comparing means of | SE(m)± | CD at 5% | | SE(m)± | CD at 5% | | SE(m)± | CD at 5% | | SE(m)± | CD at 5% | | SE(m)± | CD at 5% | |
| F | 0.14 | NS | | 0.16 | NS | | 0.14 | 0.41 | | 0.14 | NS | | 0.13 | NS | |
| P | 0.29 | 0.83 | | 0.32 | 0.93 | | 0.29 | 0.82 | | 0.28 | 0.81 | | 0.25 | 0.72 | |
| F x P | 0.41 | 1.17 | | 0.45 | 1.31 | | 0.40 | 1.16 | | 0.40 | 1.14 | | 0.36 | 1.02 | |

**Table 4. Influence of fumigants and exposure periods on seedling vigour index of groundnut seeds**

| Treatments | Months after storage | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Two | | | Four | | | Six | | | Eight | | | Ten | | |
| | F1 | F2 | Mean | F1 | F2 | Mean | F1 | F2 | Mean | F1 | F2 | Mean | F1 | F2 | Mean |
| P0 | 1096 | 1112 | 1104 | 972 | 985 | 978 | 858 | 874 | 866 | 735 | 758 | 747 | 507 | 530 | 518 |
| P1 | 1039 | 1431 | 1235 | 925 | 1329 | 1127 | 864 | 1094 | 979 | 730 | 929 | 829 | 572 | 743 | 657 |
| P2 | 1100 | 1279 | 1190 | 1036 | 1129 | 1082 | 914 | 1013 | 963 | 752 | 853 | 803 | 607 | 657 | 632 |
| P3 | 1278 | 1095 | 1186 | 1185 | 1015 | 1100 | 1012 | 894 | 953 | 864 | 746 | 805 | 597 | 581 | 589 |
| P4 | 1185 | 1039 | 1112 | 1082 | 936 | 1009 | 929 | 802 | 865 | 799 | 656 | 727 | 634 | 494 | 564 |
| P5 | 1031 | 1012 | 1022 | 838 | 849 | 844 | 713 | 809 | 761 | 579 | 657 | 618 | 447 | 494 | 470 |
| P6 | 943 | 978 | 961 | 753 | 798 | 776 | 639 | 715 | 677 | 567 | 589 | 578 | 438 | 469 | 454 |
| P7 | 889 | 908 | 898 | 746 | 769 | 757 | 625 | 671 | 648 | 533 | 568 | 551 | 402 | 411 | 407 |
| **Mean** | **1070** | **1107** | **1088** | **942** | **976** | **959** | **819** | **859** | **839** | **695** | **719** | **707** | **525** | **547** | **536** |
| For comparing means of | SE(m)± | CD at 5% | | SE(m)± | CD at 5% | | SE(m)± | CD at 5% | | SE(m)± | CD at 5% | | SE(m)± | CD at 5% | |
| F | 11.9 | 34.4 | | 13.1 | NS | | 9.9 | 28.6 | | 9.0 | NS | | 7.1 | 20.5 | |
| P | 23.9 | 68.8 | | 26.1 | 75.3 | | 19.9 | 57.2 | | 18.1 | 52.1 | | 14.2 | 41.0 | |
| F x P | 33.8 | 97.3 | | 37.0 | 106.5 | | 28.1 | 80.9 | | 25.6 | 73.7 | | 20.1 | 58.0 | |

**Table 5. Influence of fumigants and exposure periods on electrical conductivity of seed leachate ($dSm^{-1}$) of groundnut seeds**

| Treatments | Months after storage | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Two | | | Four | | | Six | | | Eight | | | Ten | | |
| | F1 | F2 | Mean | F1 | F2 | Mean | F1 | F2 | Mean | F1 | F2 | Mean | F1 | F2 | Mean |
| P0 | 0.660 | 0.675 | 0.668 | 0.840 | 0.850 | 0.845 | 0.860 | 0.880 | 0.870 | 0.940 | 0.950 | 0.945 | 0.970 | 0.975 | 0.973 |
| P1 | 0.710 | 0.480 | 0.595 | 0.880 | 0.540 | 0.710 | 0.890 | 0.690 | 0.790 | 0.960 | 0.750 | 0.855 | 0.990 | 0.820 | 0.905 |
| P2 | 0.730 | 0.520 | 0.625 | 0.840 | 0.780 | 0.810 | 0.850 | 0.730 | 0.790 | 0.880 | 0.810 | 0.845 | 0.930 | 0.900 | 0.915 |
| P3 | 0.500 | 0.730 | 0.615 | 0.690 | 0.890 | 0.790 | 0.710 | 0.910 | 0.810 | 0.780 | 0.930 | 0.855 | 0.880 | 0.960 | 0.920 |
| P4 | 0.540 | 0.760 | 0.650 | 0.830 | 0.895 | 0.862 | 0.840 | 0.930 | 0.885 | 0.880 | 0.970 | 0.925 | 0.900 | 1.002 | 0.951 |
| P5 | 0.690 | 0.770 | 0.730 | 0.900 | 0.910 | 0.905 | 0.970 | 0.950 | 0.960 | 0.990 | 0.980 | 0.985 | 1.160 | 1.080 | 1.120 |
| P6 | 0.770 | 0.780 | 0.775 | 0.845 | 0.930 | 0.888 | 0.979 | 0.960 | 0.970 | 1.110 | 0.995 | 1.053 | 1.510 | 1.330 | 1.420 |
| P7 | 0.871 | 0.720 | 0.795 | 0.970 | 0.945 | 0.958 | 0.998 | 0.988 | 0.993 | 1.200 | 1.200 | 1.200 | 1.810 | 1.612 | 1.711 |
| **Mean** | **0.684** | **0.680** | **0.682** | **0.849** | **0.842** | **0.846** | **0.887** | **0.880** | **0.883** | **0.968** | **0.948** | **0.958** | **1.144** | **1.085** | **1.114** |
| For comparing means of | SE(m)± | CD at 5% | | SE(m)± | CD at 5% | | SE(m)± | CD at 5% | | SE(m)± | CD at 5% | | SE(m)± | CD at 5% | |
| F | 0.014 | NS | | 0.014 | NS | | 0.013 | NS | | 0.020 | NS | | 0.052 | NS | |
| P | 0.027 | 0.079 | | 0.027 | 0.079 | | 0.026 | 0.075 | | 0.040 | 0.116 | | 0.103 | 0.298 | |
| F x P | 0.039 | 0.112 | | 0.039 | 0.111 | | 0.037 | 0.106 | | 0.057 | NS | | 0.146 | NS | |

recorded numerically minimum (0.680, 0.842, 0.880, 0.948 and 1.085 $dSm^{-1}$) seed leachate values. While, it was maximum (0.684, 0.849, 0.887, 0.968 and 1.144 $dSm^{-1}$) in aluminium phosphide fumigated seeds during second, fourth, sixth, eighth and tenth month of storage respectively. In general with the advancement of storage period increase in seed leachate values were noticed in the seeds fumigated with both the fumigants (Table 5).

The seeds exposed to 24 hours recorded significantly minimum (0.595, 0.710, 0.790, 0.855 and 0.905 dSm-1) seed leachate value while, it was maximum (0.795, 0.958, 0.993, 1.200 and 1.711 $dSm^{-1}$) in 168 hours exposure period during two, four, six, eight and ten months of storage respectively.

In interaction between fumigants and exposure periods, the treatment combination $F_2P_1$ recorded significantly minimum (0.480, 0.540 and 0.690 $dSm^{-1}$) seed leachate values during two, four and six months of storage respectively. While, $F_1P_7$ treatment combination recorded maximum seed leachate values during two, four, six and eight and ten months of storage, respectively. Kamble *et al*. (2013) reported the similar results in an experiment conducted on groundnut seed.

**Table 6. Influence of fumigants and exposure periods on per cent reduction in germination after ten months of storage of groundnut seeds**

| Treatments | Per cent reduction in germination(%) | | |
|---|---|---|---|
| | F1 | F2 | Mean |
| P0 | 40.77 | 39.71 | 40.24 |
| P1 | 41.13 | 31.91 | 36.52 |
| P2 | 37.94 | 37.58 | 37.76 |
| P3 | 36.52 | 39.36 | 37.94 |
| P4 | 37.58 | 42.55 | 40.07 |
| P5 | 45.39 | 42.90 | 44.15 |
| P6 | 45.74 | 43.26 | 44.50 |
| P7 | 47.15 | 46.80 | 46.98 |
| **Mean** | **41.53** | **40.51** | **41.02** |

**Per cent reduction in germination**

Initial germination per cent of the seed was 94 per cent and data on per cent reduction in germination due to fumigants, exposure periods and their interactions are presented in Table 6. Irrespective of exposure periods between the fumigants, EDB recorded minimum (40.51 %) reduction in germination while, it was maximum (41.53 %) in aluminium phosphide fumigated seeds from initial germination value to the tenth month of storage.

The exposure periods, 24 hours recorded minimum (36.52 %) reduction in germination while it was maximum (46.98 %) in 168 hours exposure period. 24, 48 and 72 hours exposure period registered minimum per cent reduction in germination compared to others from initial value to the end of storage period.

The interaction treatments, $F_2P_1$ and $F_1P_7$ recorded minimum (31.91%) and maximum (47.15 %) reduction in germination respectively at the end of storage period from the initial value (Table 6).

**Beetle population**

The data on beetle population are presented in Table 7. The seeds fumigated with aluminium phosphide allowed least (1.08, 2.17, 2.13, 2.71 and 3.21) number of groundnut beetles to survive while, maximum number (1.33, 2.58, 2.75, 3.67 and 4.33) survived in EDB fumigated seeds during two, four, six, eight and ten months of storage, respectively.

Among the exposure periods, unfumigated seeds recorded highest (5.50, 8.00, 10.00, 11.33 and 12.50) number of groundnut beetle while, it was least (0.00, 0.00, 0.00, 0.00 and 1.00) in seeds exposed to 168 hours for fumigants at the end of two, four, six, eight and ten months of storage, respectively.

With the advancement of storage period, per cent infestation of seeds was increased whereas, increase in exposure periods for fumigants reduced the pest population.

The seeds fumigated with EDB for 24 hours exposure period ($F_2P_1$) recorded highest (3.00, 4.33, 4.67, 5.33 and 5.33) number of insects while, the insect population was considerably reduced (0.00, 0.00, 0.00, 0.00 and 1.00) in seeds fumigated with aluminium phosphide for 168 hours exposure period ($F_1P_7$) during second, fourth, sixth, eighth and tenth month of storage respectively. Kamble *et al*. (2013) reported the similar results in an experiment conducted on groundnut seed.

**Table 7. Influence of fumigants and exposure periods on beetle population in groundnut seeds.**

| Treatments | Months after storage | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Two | | | Four | | | Six | | | Eight | | | Ten | | |
| | F1 | F2 | Mean | F1 | F2 | Mean | F1 | F2 | Mean | F1 | F2 | Mean | F1 | F2 | Mean |
| P0 | 5.33 | 5.67 | 5.50 | 7.33 | 8.67 | 8.00 | 9.33 | 10.67 | 10.00 | 11.00 | 11.67 | 11.33 | 11.67 | 13.33 | 12.50 |
| P1 | 2.33 | 3.00 | 2.67 | 3.33 | 4.33 | 3.83 | 3.33 | 4.67 | 4.00 | 3.33 | 5.33 | 4.33 | 4.00 | 5.33 | 4.67 |
| P2 | 1.00 | 1.00 | 1.00 | 3.00 | 2.00 | 2.50 | 2.00 | 2.33 | 2.17 | 3.67 | 4.67 | 4.17 | 3.33 | 5.00 | 4.17 |
| P3 | 0.00 | 1.00 | 0.50 | 1.00 | 1.00 | 1.00 | 0.00 | 1.00 | 0.50 | 1.00 | 2.00 | 1.50 | 1.00 | 2.67 | 1.83 |
| P4 | 0.00 | 0.00 | 0.00 | 1.67 | 2.00 | 1.83 | 1.33 | 2.00 | 1.67 | 1.67 | 2.67 | 2.17 | 2.00 | 3.33 | 2.67 |
| P5 | 0.00 | 0.00 | 0.00 | 1.00 | 1.67 | 1.33 | 1.00 | 1.33 | 1.17 | 1.00 | 2.00 | 1.50 | 1.67 | 2.33 | 2.00 |
| P6 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.50 | 1.00 | 1.67 | 1.33 |
| P7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 1.00 |
| **Mean** | **1.08** | **1.33** | **1.21** | **2.17** | **2.58** | **2.38** | **2.13** | **2.75** | **2.44** | **2.71** | **3.67** | **3.19** | **3.21** | **4.33** | **3.77** |

## CONCLUSION

The seeds fumigated with Ethylene dibromide for 24 hours exposure period (F2P1) recorded higher seed quality parameters during entire storage period. This was followed by the seeds fumigated with Aluminium phosphide for 72 hours exposure period (F1P3). The seeds fumigated with Ethylene dibromide for 24 hours exposure period recorded satisfactory germination of 70 per cent up to eight months of storage while, the seeds fumigated with aluminium phosphide for 96 hours exposure period could maintain it up to six month of storage period only.

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# Yield and Monetary Returns of Chickpea *(Cicer arietinum* L.*)* as Influenced by Organic Fertilizers under Irrigated Condition

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## ABSTRACT

A field experiment was conducted during *Rabi* season, 2016-17 at the Research Farm of All India Coordinated Research Project on Integrated Farming System, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MS) with an objective to study the effect of organic fertilizers on yield and monetary returns of chickpea. Result revealed that the seed yield (1972 kg ha$^{-1}$) of chickpea was recorded significantly highest with 100 per cent N (RDF) + 200 per cent P&K (through organic fertilizers) and found at par with 100 per cent N (RDF) + 150 per cent P&K (through organic fertilizers) and 100 per cent N (RDF) + 150 per cent K (through organic fertilizers) and significant over the rest of treatments. Straw yield (3966 kg ha$^{-1}$) and biological yields (5938 kg ha$^{-1}$) were also observed significantly higher in 100 per cent N (RDF) + 200 per cent P&K (through organic fertilizers) and found at par with 100 per cent N (RDF) + 150 per cent P&K (through organic fertilizers) and superior over other treatments. Significantly highest gross monetary return was noticed with 100 per cent N + 200 per cent P & K (through organic fertilizers) which was nearly followed by treatment $T_4$. Likewise, net monetary return was obtained significantly higher in 100 per cent N & P (RDF) + K(through organic fertilizers) with highest B:C ratio of 2.88. Whereas, the harvest index was recorded maximum (37.32 %) in 100 per cent N (RDF) + 100 per cent P&K (through organic fertilizers) but found at par with treatments $T_7$, $T_6$ and $T_4$ and significant over other treatments.


India is self-sufficient in respect of food grain production but still lags behind in production of pulses. Moreover, burgeoning population pressure and increasing protein malnutrition aggravate the problem and call for stepping up the pulses production. Pulses are major and cheaper source of protein particularly for vegetarians and contribute about 14 per cent of Indian diet. Further 16.7 per cent of the total protein of an Indian average diet is derived from pulses. Their inclusion as main, catch, cover, green manure and intercrop rotation in farming system is found all over the World.Production of pulses is far below the requirement to meet even the minimum level of per capita consumption (70 g day$^{-1}$ capita$^{-1}$ prescribed by ICMR) which causes malnutrition among the growing people.

Chickpea, a member of Fabaceae family, also known as ‘Gram or Bengal gram’, It is one of the major pulse in India and in many other countries. It is predominantly grown in cool, dry periods on receding soil moisture. Pulses are a primary source of nourishment and, when combined with cereals, provide a nutritionally balanced low cost food for human being.In addition, chickpea is a good source of energy, protein, minerals, vitamins, fiber and contains potentially health beneficial phytochemicals. It is the main source of vegetable protein in human diet as it contains 21 per cent protein and 38-59 per cent carbohydrates (Gupta, 1989).

In India, chickpea is grown on 9.93 million hectare area with 9.53 million tones production and 960 kg ha$^{-1}$ productivity in rabi season (Anonymous, 2015[a]). Among the chickpea producing states in India, Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh and Rajasthan are the major chickpea states. Maharashtra is one of the important chickpea growing state in India and ranked second next to the state of Madhya Pradesh. In Maharashtra the area under chickpea was 17.74 lakh hectares with production of 15.07 lakh tones and productivity of 850 kg ha$^{-1}$, whereas, in Vidarbha region, chickpea was grown on an area of 5.53 lakh hectares with production of 3.80 lakh tones and productivity of 1355 kg ha$^{-1}$ (Anonymous, 2015[b]).

The management of organic fertilizer might have significant effect on growth, yield and economy of chickpea. Balanced fertilization is always necessary to maintain good residual soil fertility status. Besides

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inorganic fertilizers, the use of organic source of nutrients to the chickpea enhances the productivity in terms of seed yield. The organic fertilizer not only enhances the productivity but also maintain good soil health.

Among the several nutrients responsible for crop production, phosphorous and potassium plays an important role. The current trend is to explore the possibility of supplementing phosphorous and potassium through chemical fertilizers with organic one to sustain yield and economic level.

## MATERIAL AND METHODS

A field experiment was carried out during *rabi* season, 2016-17 at the research farm of All India Coordinated Research Project on Integrated Farming System, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MS) with an objective to study the effect of organic fertilizers on yield and economics of chickpea. The field selected for the experimentation was fairly uniform and leveled. Soil of experimental plot was inceptisol and clayey (58.3 %). It was low in available nitrogen (208.32 kg $ha^{-1}$) and phosphorous (17.65 kg $ha^{-1}$), moderate in organic carbon (0.58 %), rich in available potassium (351.70 kg $ha^{-1}$) and slightly alkaline (7.7) in reaction. The total rainfall recorded from October, 2016 to February, 2017 during crop growing season was 91.0 mm received in 5 rainy days as against normal rainfall of 102.6 mm and total rainy days of 7.2. Bright sunshine hours temperature, wind speed were lower than normal that helped the crop to utilize available soil moisture for longer period and kept the evaporation losses less which favored the crop growth. The experiment was laid out in randomized block design with eight treatments and three replications. The crop variety was JAKI-9218 drilled at the spacing 30 cm ×15 cm under protective irrigation. The treatments comprising, $T_1$- 100 per cent NPK (RDF) through chemical fertilizers, $T_2$-100 per cent N + 50 per cent P&K (RDF)+ 50 per cent P&K (through organic fertilizers),$T_3$-100 per cent N (RDF) + 100 per cent P & K(through organic fertilizers), $T_4$- 100 per cent N(RDF) + 150 per cent P & K(through organic fertilizers),$T_5$- 100 per cent N (RDF) + 200 per cent P & K (through organic fertilizers),$T_6$- 100 per cent N & P (RDF) + 100 per cent K (through organic fertilizers),$T_7$- 100 per cent N & P (RDF) + 150 per cent K (through organic fertilizers) and $T_8$- 100 per cent N & K (RDF) + 100 per cent P (through organic fertilizers). The recommended dose of fertilizers for chickpea is 25 + 50 + 30 NPK kg $ha^{-1}$. The organic P & K fertilizers were used in the present experiment for investigation, by keeping the common (100 %) recommended dose of nitrogen for all the treatments and the doses of P & K, were adjusted as per treatments were applied through chemical fertilizers. Similarly, treatment wise, recommended doses were calculated for phosphorous and potassium and applied through organic fertilizers. The organic phosphatic fertilizer (pre- mixture) contains rock phosphate, compost, leaf extract of banyan, bermuda, kokum and tulsi. The pre-mixture contents 10.42 per cent phosphate, 0.43 per cent nitrogen, 7.87 per cent organic carbon, having 18.30 C: N ratio and 25 per cent moisture by weight. While, potassic fertilizer (pre- mixture) contains ash, compost & leaf extract of banyan, bermuda, kokum &tulsi. The pre-mixture contents 10 per cent potash, 15 per cent potassium humate and 7.48 per cent organic carbon.All the fertilizers and time to time field operations were carried out in the experiment as per the treatments and University recommended package of practice

## RESULTS AND DISCUSSION

### Seed, straw, biological yields and harvest index of chickpea

The data (Table 1) on seed, straw, biological yields and harvest index of chickpea were significantly influenced by various organic treatments. Result revealed that significantly highest seed yield (1972kg $ha^{-1}$) was recorded in 100 per cent N (RDF) + 200 per cent P&K (through organic fertilizers) which was found at par with 100per cent N (RDF) + 150 per cent P&K ( through organic fertilizers) and 100 per cent N & P (RDF) + 150 per cent K (through organic fertilizers) and superior over the rest of treatments. Lower seed yield was observed in 100per cent NPK (RDF) applied through chemical fertilizers. The increase in yield might be due to increased photosynthetic production and translocation of photosynthetic product towards seed production. These results were in agreement with the findings of Jadeja *et al.* (2016).

The significantly highest straw yield of chickpea (3966 kg $ha^{-1}$) was recorded in 100 per cent N (RDF) + 200 per cent P & K ( through organic fertilizers) and found at par with 100 per cent N (RDF) + 150 per cent P & K (

**Table 1:Seed yield, straw yield, biological yield and harvest index of chickpea as influenced by different treatments**

| Symbol | Treatment | Seed yield (kg ha$^{-1}$) | Straw yield (kg ha$^{-1}$) | Biological yield (kg ha$^{-1}$) | Harvest index (%) |
|---|---|---|---|---|---|
| $T_1$ | 100% NPK (RDF) through chemical fertilizers | 1126 | 3074 | 4200 | 27.03 |
| $T_2$ | 100% N + 50% P & K (RDF) + 50% P & K (through organic fertilizers) | 1188 | 2880 | 4069 | 29.39 |
| $T_3$ | 100% N (RDF) + 100% P & K(through organic fertilizers) | 1796 | 3063 | 4859 | **37.32** |
| $T_4$ | 100% N (RDF) + 150% P & K(through organic fertilizers) | 1942 | 3848 | 5791 | 33.71 |
| $T_5$ | 100% N (RDF) + 200% P & K (through organic fertilizers) | **1972** | **3966** | **5938** | 33.37 |
| $T_6$ | 100% N & P (RDF) + 100% K (through organic fertilizers) | 1682 | 3240 | 4921 | 34.46 |
| $T_7$ | 100%N & P (RDF) + 150% K (through organic fertilizers) | 1849 | 3344 | 5193 | 35.64 |
| $T_8$ | 100% N & K (RDF) + 100% P (through organic fertilizers) | 1271 | 2864 | 4135 | 31.02 |
| | SE (m) ± | 32.69 | 145.21 | 149.65 | 1.30 |
| | CD @5% | 99.16 | 440.5 | 453.98 | 3.94 |

through organic fertilizers) and superior over the rests. Likewise, treatment $T_7$ recorded significantly maximum straw yield and found at par with $T_6$, $T_1$ and $T_3$. The lowest straw yield was noticed in treatment $T_8$ followed by $T_2$.

The significantly highest biological yield (5938 kg ha$^{-1}$) was observed in 100 per cent N (RDF) + 200 per cent P & K (through organic fertilizers) but found at par with treatment $T_6$ and $T_3$. Treatments $T_1$, $T_8$ and $T_2$ were found at par with eachother. The lowest biological yield was noticed in treatment $T_2$. It might be due to various organic fertilizer levels that attributed to variation in the number of branches, plant height and seed yield. Similar results were corroborated by Verma *et al.* (2017).

The mean harvest index (32.74 %) was recorded and significantly highest harvest index (37.32 %) was observed in 100 per cent N (RDF) + 100 per cent P&K (through organic fertilizers) but found at par with treatments $T_7$, $T_6$ and $T_4$. Whereas, the lowest values of harvest index was noted in 100 per cent NPK (RDF) through chemical fertilizers.

**Economics of chickpea**

**Gross monetary returns**

Data pertaining to gross monetary returns, net monetary returns and B:C ratiowereinfluenced by various treatments (Table 2). Results revealed that the highestgross monetary returns (Rs.94735 ha$^{-1}$) was recorded significantly highest in 100 per cent N (RDF) + 200 per cent P&K (through organic fertilizers) which was nearly followed by 100 per cent N (RDF) + 150 per cent P&K (through organic fertilizers) but found at par with each other and superior over others. Similarly treatment 100 per centN (RDF) + 150 per cent K (through organic fertilizers) recorded significantly more gross monetary returns and comparable with 100 per cent N (RDF) + 100 per cent P and K (through organic fertilizers) and found superior over rests. Whereas, the lowest gross monetary returns was noted in treatment of 100 per cent NPK (RDF) applied through chemical fertilizers. Highergross monetary returns might be due to producing more seed and straw yields of chickpea. Similar results were obtained by Kadam *et al.* (2014).

**Cost of cultivation**

Numerically higher cost of cultivation(Rs. 44964 ha$^{-1}$) was noticed in 100 per cent N (RDF) + 200 per cent P and K (through organic fertilizers) and lowest in 100 per cent NPK (RDF) applied through chemical fertilizers.

**Net monetary returns**

Significantly highest net monetary returns (Rs.57205 ha$^{-1}$) were recorded in 100 per cent N and P (RDF) + 150 per cent K (through organic fertilizers) and found superior over rest of the treatments. Whereas, the lowest net monetary returns were observed in 100 per cent N + 50 per cent P and K (RDF) + 50 per cent P and K (through organic fertilizers). These results are supported by the findings of Meena and Biswas (2013).

**Table 2: Gross monetary, net monetary and benefit : cost ratio (Economics) in chickpea as influenced by different treatments**

| Symbol | Treatment | GMR (Rs ha$^{-1}$) | COC (Rs ha$^{-1}$) | NMR (Rs ha$^{-1}$) | B:C ratio |
|---|---|---|---|---|---|
| T1 | 100% NPK (RDF) through chemical fertilizers | 56513 | 24645 | 29948 | 2.13 |
| T2 | 100% N + 50% P & K (RDF) + 50% P & K (through organic fertilizers) | 58551 | 28986 | 27645 | 1.89 |
| T3 | 100% N (RDF) + 100% P & K(through organic fertilizers) | 84620 | 33327 | 49373 | 2.40 |
| T4 | 100% N (RDF) + 150% P & K(through organic fertilizers) | 93123 | 39145 | 52058 | 2.27 |
| T5 | 100% N (RDF) + 200% P & K (through organic fertilizers) | 94735 | 44964 | 47851 | 2.02 |
| T6 | 100% N & P (RDF) + 100% K (through organic fertilizers) | 80349 | 27065 | 51364 | 2.77 |
| T7 | 100% N & P (RDF) + 150% K (through organic fertilizers) | 87690 | 28565 | 57205 | 2.88 |
| T8 | 100% N & K (RDF) + 100% P (through organic fertilizers) | 61961 | 30907 | 29134 | 1.89 |
| | Se (m) ± | 1451 | - | 1451 | - |
| | CD @5% | 4443 | - | 4443 | - |

**Benefit : cost ratio**

Similarly, the highest benefit cost ratio (2.88) was noticed in 100 per cent N and P (RDF) + 150 per cent K (through organic fertilizers) and found at par with 100 per cent N and P (RDF) + 100 per cent K (through organic fertilizers). While, the lower and similar benefit cost ratio (1.89) was observed in 100 per cent N and &K (RDF) + 100 per cent P (through organic fertilizers) and 100 per cent N+ 50 per cent P and K (RDF) + 50 per cent P and K(through organic fertilizers). These results were in agreement with the findings of Patil *et al*. (2011).

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# Effect of Foliar Nutrition on Productivity of Soybean under rainfed condition

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## ABSTRACT

The field experiment was conducted at Regional Research Center, Amravati during three *kharif* season from 2015-16 to 2017-18. The experiment was laid out in Randomized block design with three replications consisting of nine treatments comprising of RDF + water spray at pod initiation (T1), RDF + Urea @ 2 per cent spray at pod initiation (T2), RDF + DAP @ 2 per cent spray at pod initiation (T3), RDF + MOP @ 0.5 per cent at pod initiation (T4), RDF + 19:19:19 (NPK) @ 2 per cent at pod initiation (T5), RDF + Molybdenum @ 0.5 per cent at pod initiation (T6), RDF + Boron @ 0.5 per cent at pod initiation (T7), RDF +Zinc chelated @ 0.5 per cent at pod initiation (T8) and RDF only (T9). Yield attributes *viz*., branches plant$^{-1}$, pods per plant, seed index and seed yield and straw yield was recorded at the time of harvesting. Highest number of pods per plant was observed in treatment RDF + DAP @ 2 per cent at pod initiation stage (20.42) followed byRDF + 19:19:19 (NPK) @ 2 per cent at pod initiation and RDF + Boron @ 0.5 per cent at pod initiation. Seed and straw yield (2056 and 2706 kg ha$^{-1}$, respectively) was recorded significantly highest in treatment RDF + DAP@ 2 per cent at pod initiation stage but found at par with RDF + 19:19:19 (NPK) @ 2 per cent at pod initiation.

Soybean (*Glycine max* (L.) Merill.) is known as Chinesepea or Manchurian bean which belongs to familyLeguminaceae and originated in Asia. It is the miracle crop which has phenomenal growth and production. It has vital importance in Indian Agriculture, but also plays a decisive role in oil economy of India. It is the cheapest and main sourceof dietary protein of majority vegetarian Indians. Soybean seed consists of 18-20 per cent oil and 30-50 per cent protein (Vahedi, 2011).The increasing cost of fertilizer nutrients have led to search for alternative practices of managing the fertilizer nutrients more judiciously, efficiently and in balance proportions. Such approach would reduce the depletion of macro and micronutrients from soil. Among the nutrients,macro-nutrients have been given the priority and little attention has been paid towards micronutrients. In the absence of micronutrients, plant shows physiological disorders which eventually lead to low crop yield and impaired quality.Now a day's most of the farmers are alert regarding adoption of recommended dose of fertilizer, incorporation of FYM, compost and crop residues as well as seed treatment with bio-fertilizers etc. for getting higher yield. Many references are quoted by scientist that supplemental nutrients applied at proper growth stage of crop through foliar application increases the yield of soybean. At reproductive growth stage i.e. flowering or pod initiation stage, crop requires more nutrients for development of reproductive organ along with sufficient soil moisture.

Foliar spraying is a method for crop feeding in which micronutrients in the form of liquid are used on leaves (Nasiri *et al*., 2010). Foliar application of micronutrient is beneficial like soil application. Since application rates are lesser as compared to soil application, same quantity of nutrient application could be supplied easilyand crop reacts to nutrient application immediately. Foliar spraying of micronutrient is very helpful when the roots arenot able to provide necessary nutrients. Crop roots are unable to absorb some important nutrients such as zinc, because of soil properties, such as high pH, lime or heavy texture and in this situation, foliar spraying is better as compared to soil application (Kinaci and Gulmezoglu, 2007).

At reproductive growth stage, application of only major nutrients is not sufficient. The crop also requires micronutrient for development. Considering their importance the present investigation was undertaken to supply the major and micronutrients through foliar at reproductive growth stage of soybean to get higher seed yield.

## MATERIAL AND METHODS

The field experiment was conducted in field at Regional Research Center, Amravati during three successive *kharif* season from 2015-16 to 2017-18. The experiment site was fairly uniform, leveled and have

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medium black soil. The experiment was laid out in Randomized block design with three replications consisting of nine treatments comprising of RDF + water spray at pod initiation (T1), RDF + Urea @ 2 per cent spray at pod initiation (T2), RDF + DAP @ 2 per cent spray at pod initiation (T3), RDF + MOP @ 0.5 per cent at pod initiation (T4), RDF + 19:19:19 (NPK) @ 2 per cent at pod initiation (T5), RDF + Molybdenum @ 0.5 per cent at pod initiation (T6), RDF + Boron @ 0.5 per cent at pod initiation (T7), RDF +Zinc chelated @ 0.5 per cent at pod initiation (T8) and RDF only (T9)

Soil type was medium black with 0.52 per cent OC and initial status of soil was 190, 15.50, 338.09 kg NPK respectively. After seed bed preparation, sowing of soybean cv JS-95-60 was done by dibbling. Recommended dose of fertilizer (30:75:30:20 NPKS kg $ha^{-1}$) was given at the sowing time. Foliar application of molybdenum and boron were given through ammonium molybdate and borax, respectively. The observation on dry matter was recorded at 30 DAS, 45 DAS and 60 DAS, CGR and RGR on 30-45 and 45-50 DAS. Yield attributes *viz*., branches $plant^{-1}$, pods $plant^{-1}$, seed index and seed yield kg $ha^{-1}$ and straw yield kg $ha^{-1}$ was recorded at the time of harvesting.

## RESULTS AND DISCUSSION

### Yield attributes

The significantly highest number of branches per plant was observed in treatment of RDF + Molybdenum @ 0.5 per cent spray at pod initiation stage(2.46) but found at par with almost all treatments except RDF + water spray and RDF (Table 1).

Significantly higher number of pods per plant was observed in treatment of RDF + DAP @ 2 per cent spray at pod initiation (20.42) but found at par with RDF + 19:19:19 (NPK) @ 2 per cent spray at pod initiation (19.48) and RDF + Boron @ 0.5 per cent spray at pod initiation (19.47). Similar results were reported by Vinoth Kumar *et al*. (2013). The foliar application of nutrients through 2 per cent DAP at flower initiation and pod formation stage might have reduced flower drop. This might have significantly increased the number pods $plant^{-1}$ as reported by Ganapathy *et al*. (2008). The pooled data over three years, indicated that at 45 DAS, highest dry matter (Table 2) was recorded in treatment of RDF + water spray at pod initiation (6.92 g), but it was observed at par with treatment of foliar spray of urea, DAP and 19:19:19 in addition to RDF. While at 60 DAS, treatment of. RDF + DAP @2per cent spray at pod initiation proves significantly superior over rest of the treatment andhighest dry matter accumulation (11.87 g).

Significantly highest dry matter accumulation was found in RDF + 19:19:19 (NPK) @ 2 per cent at pod initiation (23.46 g) but found on par with treatment of RDF+Urea @ 2 per cent, RDF+DAP @ 2 per cent and RDF+ chelated zinc @ 0.5 .

### Seed and Straw yield

The pooled data indicated that significantly highest seed and straw yield (2056 and 2706 kg $ha^{-1}$) was recorded in treatment of RDF + DAP @ 2 per cent spray at pod initiation stage and found at par with RDF + 19:19:19 (NPK) @ 2 per cent at pod initiation (Table 3).

The result showed positive effect of supplying soybean with supplementary nitrogen to have beneficial effects on enhancing growth and seed yield. Similar observations were also reported by Ashour and Thalooth (1983) and Das and Jana (2015). According to Mannan (2014), foliar spraying during the pod filling stage is more effective than vegetative stage because nutrients applied during pod filling is readily used for photosynthesis and assimilates quickly mobilized towards grain filing and protein accumulation in grain.

The highest Harvest Index was observed in treatment RDF + chelated Zinc @ 0.5 per cent spray at pod initiation ( 44.39 %). The seed index was not influenced significantly.

Maximum rain use efficiency and grain production efficiency was recorded in treatment RDF + DAP @ 2 per cent spray at pod initiation (T3) i. e. 2.94 kg $ha^{-1}$ mm and 22.85 $kg^{-1}$ $ha^{-1}$ $day^{-1}$, respectively.

### Monetary return

The pooled data showed that, maximum cost of cultivation of Rs. 41509 per ha was observed with treatment of RDF + Molybdenum @0.5 per cent at pod initiation while significantly highest gross and net monitory returns

**Table 1.Effect of foliar nutrition on branches and pods plant$^{-1}$**

| Treatment | Branches plant$^{-1}$ | | | | Pods plant$^{-1}$ | | | |
|---|---|---|---|---|---|---|---|---|
| | 2015-16 | 2016-17 | 2017-18 | Pooled | 2015-16 | 2016-17 | 2017-18 | Pooled |
| $T_1$ RDF + water spray at pod initiation | 2.00 | 1.47 | 2.20 | 1.89 | 14.53 | 18.67 | 17.40 | 16.87 |
| $T_2$ RDF + Urea @ 2 % spray at pod initiation | 2.33 | 2.23 | 2.27 | 2.28 | 13.93 | 20.87 | 16.80 | 17.20 |
| $T_3$ RDF + DAP @ 2 % spray at pod initiation | 2.07 | 2.23 | 2.53 | 2.28 | 15.73 | 23.87 | 21.67 | 20.42 |
| $T_4$ RDF + MOP @ 0.5 % at pod initiation | 1.47 | 2.33 | 2.80 | 2.20 | 14.13 | 22.40 | 19.20 | 18.58 |
| $T_5$ RDF + 19:19:19 (NPK) @ 2 % at pod initiation | 2.43 | 2.40 | 2.07 | 2.30 | 15.40 | 22.87 | 20.17 | 19.48 |
| $T_6$ RDF + Molybdenum @ 0.5 % at pod initiation | 2.03 | 2.40 | 2.93 | 2.46 | 11.87 | 23.90 | 19.73 | 18.50 |
| $T_7$ RDF + Boron @ 0.5 % at pod initiation | 2.37 | 2.47 | 2.33 | 2.39 | 14.87 | 23.40 | 21.33 | 19.87 |
| $T_8$ RDF + chelated Zinc @ 0.5 % at pod initiation | 2.00 | 2.47 | 2.73 | 2.40 | 12.87 | 22.80 | 17.27 | 17.64 |
| $T_9$ RDF only | 1.57 | 1.53 | 2.40 | 1.83 | 11.13 | 19.47 | 16.93 | 15.84 |
| SE (m) ± | 0.13 | 0.10 | 0.32 | 0.13 | 0.87 | 1.03 | 1.14 | 0.59 |
| CD (P=0.05) | 0.39 | 0.29 | NS | 0.38 | 2.61 | 3.09 | 3.42 | 1.77 |

**Table 2. Effect of foliar nutrition on dry matter accumulated (g $plant^{-1}$) at periodical intervals**

| Treatment | At 30 DAS | | | | at45 DAS | | | | At 60 DAS | | | | At Harvest | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015-16 | 2016-17 | 2017-18 | Pooled | 2015-16 | 2016-17 | 2017-18 | Pooled | 2015-16 | 2016-17 | 2017-18 | Pooled | 2015-16 | 2016-17 | 2017-18 | Pooled |
| $T_1$ RDF + water spray at pod initiation | 1.56 | 1.61 | 2.03 | 1.74 | 7.92 | 6.04 | 6.80 | 6.92 | 8.48 | 8.70 | 8.74 | 8.64 | 19.17 | 19.57 | 16.85 | 18.53 |
| $T_2$ RDF + Urea @2 % spray at pod initiation | 2.67 | 2.79 | 2.36 | 2.61 | 6.66 | 6.26 | 7.16 | 6.70 | 8.63 | 10.53 | 12.17 | 10.44 | 23.41 | 24.07 | 21.09 | 22.86 |
| $T_3$ RDF +DAP @2 % spray at pod initiation | 2.32 | 2.43 | 2.32 | 2.36 | 6.91 | 6.13 | 7.58 | 6.87 | 8.78 | 13.98 | 12.86 | 11.87 | 23.12 | 23.30 | 22.33 | 22.92 |
| $T_4$ RDF + MOP @0.5 % at pod initiation | 1.83 | 1.95 | 2.20 | 1.99 | 6.10 | 5.48 | 6.44 | 6.01 | 6.87 | 10.76 | 10.98 | 9.54 | 19.43 | 20.14 | 17.11 | 18.89 |
| $T_5$ RDF + 19:19:19 (NPK) @2 % at pod initiation | 2.35 | 2.46 | 2.31 | 2.37 | 6.23 | 6.93 | 7.28 | 6.81 | 9.60 | 10.61 | 11.23 | 10.48 | 24.34 | 24.02 | 22.02 | 23.46 |
| $T_6$ RDF + Molybdenum @0.5per cent at pod initiation | 2.69 | 2.80 | 2.30 | 2.60 | 5.59 | 5.80 | 6.77 | 6.05 | 7.80 | 9.59 | 11.20 | 9.53 | 20.02 | 20.84 | 17.70 | 19.52 |
| $T_7$ RDF + Boron @0.5 % at pod initiation | 1.80 | 1.88 | 2.26 | 1.98 | 5.22 | 5.72 | 6.11 | 5.68 | 7.72 | 9.14 | 11.27 | 9.38 | 19.85 | 19.98 | 17.53 | 19.12 |
| $T_8$ RDF + chelated Zinc @0.5 % at pod initiation | 2.32 | 2.43 | 2.20 | 2.31 | 5.51 | 6.16 | 6.57 | 6.08 | 8.61 | 8.13 | 10.25 | 9.00 | 22.27 | 22.15 | 19.95 | 21.46 |
| $T_9$ RDF only | 1.70 | 1.92 | 2.05 | 1.89 | 5.10 | 5.66 | 6.90 | 5.89 | 7.78 | 7.35 | 8.35 | 7.83 | 19.04 | 19.41 | 16.72 | 18.39 |
| SE(m) ± | 0.14 | 0.17 | 0.11 | 0.13 | 0.39 | 0.36 | 0.29 | 0.16 | 0.46 | 0.52 | 0.68 | 0.37 | 1.16 | 1.01 | 1.16 | 1.09 |
| CD at 5% | 0.42 | 0.51 | NS | 0.38 | 1.16 | NS | NS | 0.49 | 1.37 | 1.55 | 2.04 | 1.10 | 3.48 | 3.01 | 3.49 | 3.26 |

Table 3. Effect of foliar nutrition on seed and straw yield of soybean

| Treatment | | Seed Yield (kg $ha^{-1}$) | | | | Straw Yield (kg $ha^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2015-16 | 2016-17 | 2017-18 | Pooled | 2015-16 | 2016-17 | 2017-18 | Pooled |
| $T_1$ | RDF + water spray at pod initiation | 1468 | 1837 | 1565 | 1623 | 1970 | 2489 | 1967 | 2142 |
| $T_2$ | RDF + Urea @2 % spray at pod initiation | 1368 | 2104 | 1576 | 1682 | 1827 | 2882 | 1930 | 2213 |
| $T_3$ | RDF + DAP @2 % spray at pod initiation | 1571 | 2433 | 2165 | 2056 | 2084 | 3358 | 2677 | 2706 |
| $T_4$ | RDF + MOP @0.5 % at pod initiation | 1424 | 2268 | 1852 | 1848 | 1816 | 2953 | 2215 | 2328 |
| $T_5$ | RDF + 19:19:19 (NPK) @2 % at pod initiation | 1599 | 2340 | 1898 | 1946 | 2131 | 3114 | 2334 | 2526 |
| $T_6$ | RDF + Molybdenum @0.5 % at pod initiation | 1169 | 2422 | 1846 | 1812 | 1539 | 3254 | 2265 | 2353 |
| $T_7$ | RDF + Boron @0.5 % at pod initiation | 1454 | 2333 | 1951 | 1913 | 1894 | 2996 | 2430 | 2440 |
| $T_8$ | RDF + chelated Zinc @0.5 % at pod initiation | 1278 | 2291 | 1579 | 1716 | 1520 | 3022 | 1981 | 2174 |
| $T_9$ | RDF only | 1108 | 1930 | 1536 | 1525 | 1350 | 2466 | 1966 | 1927 |
| SE(m)± | | 91.22 | 99.14 | 117.61 | 53.80 | 118.46 | 142.21 | 152.48 | 70.90 |
| CD at 5% | | 273.45 | 297.20 | 352.56 | 161.28 | 355.10 | 426.29 | 457.08 | 212.55 |

**Table 4. Effect of foliar nutrition on seed and harvest index of soybean**

| Treatment | Seed Index (g) | | | | Harvest Index (per cent) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2015-16 | 2016-17 | 2017-18 | Pooled | 2015-16 | 2016-17 | 2017-18 | Pooled |
| T1 RDF + water spray at pod initiation | 12.67 | 11.74 | 11.03 | 11.81 | 42.68 | 42.44 | 44.31 | 43.14 |
| T2 RDF + Urea @2 % spray at pod initiation | 12.33 | 11.77 | 11.23 | 11.78 | 42.87 | 42.19 | 45.10 | 43.39 |
| T3 RDF + DAP @2 % spray at pod initiation | 12.37 | 11.80 | 11.80 | 11.99 | 42.98 | 42.02 | 44.67 | 43.22 |
| T4 RDF + MOP @0.5 % at pod initiation | 12.40 | 11.72 | 11.41 | 11.84 | 43.91 | 43.50 | 45.47 | 44.29 |
| T5 RDF + 19:19:19 (NPK) @2 % at pod initiation | 12.73 | 11.85 | 11.16 | 11.91 | 42.93 | 42.93 | 44.86 | 43.58 |
| T6 RDF + Molybdenum @0.5 % at pod initiation | 12.27 | 11.74 | 11.16 | 11.72 | 43.20 | 42.68 | 44.91 | 43.60 |
| T7 RDF + Boron @0.5 % at pod initiation | 12.23 | 11.79 | 11.10 | 11.71 | 43.36 | 43.77 | 44.58 | 43.90 |
| T8 RDF + chelated Zinc @0.5 % at pod initiation | 12.13 | 11.77 | 11.01 | 11.64 | 45.66 | 43.11 | 44.39 | 44.39 |
| T9 RDF only | 12.23 | 11.75 | 11.09 | 11.69 | 45.14 | 43.93 | 43.86 | 44.31 |
| SE(m)± | 0.13 | 0.02 | 0.18 | 0.08 | — | — | — | — |
| CD at 5% | NS | NS | NS | NS | — | — | — | — |

**Table 5. Effect of foliar nutrition on grain production efficiency and rain use efficiency of soybean**

| Treatment | Grain Production Efficiency (kg $ha^{-1}day^{-1}$) | | | | RUE (kg $ha^{-1}$-mm) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2015-16 | 2016-17 | 2017-18 | Pooled | 2015-16 | 2016-17 | 2017-18 | Pooled |
| T1 RDF + water spray at pod initiation | 16.31 | 20.41 | 17.39 | 18.04 | 2.16 | 2.15 | 2.64 | 2.32 |
| T2 RDF + Urea @2 % spray at pod initiation | 15.20 | 23.37 | 17.51 | 18.69 | 2.01 | 2.46 | 2.66 | 2.38 |
| T3 RDF + DAP 2 % spray at pod initiation | 17.45 | 27.03 | 24.05 | 22.85 | 2.31 | 2.84 | 3.65 | 2.94 |
| T4 RDF + MOP @0.5 % at pod initiation | 15.83 | 25.19 | 20.58 | 20.53 | 2.10 | 2.65 | 3.12 | 2.62 |
| T5 RDF + 19:19:19 (NPK) @2 % at pod initiation | 17.77 | 26.00 | 21.09 | 21.62 | 2.36 | 2.73 | 3.20 | 2.76 |
| T6 RDF + Molybdenum @0.5 % at pod initiation | 12.99 | 26.91 | 20.52 | 20.14 | 1.72 | 2.83 | 3.11 | 2.56 |
| T7 RDF + Boron @0.5 % at pod initiation | 16.15 | 25.92 | 21.68 | 21.25 | 2.14 | 2.73 | 3.29 | 2.72 |
| T8 RDF + chelated Zinc @0.5 % at pod initiation | 14.20 | 25.46 | 17.54 | 19.06 | 1.88 | 2.68 | 2.66 | 2.41 |
| T9 RDF only | 12.31 | 21.45 | 17.07 | 16.94 | 1.63 | 2.25 | 2.59 | 2.16 |
| SE (m) ± | — | — | — | — | — | — | — | — |
| CD at 5% | — | — | — | — | — | — | — | — |

Table 6. Effect of foliar nutrition on Economics of soybean

| Treatment | Cost of Cultivation (Rs $ha^{-1}$) | | | | Gross Monitory Returns (Rs $ha^{-1}$) | | | | Net Monitory Returns (Rs $ha^{-1}$) | | | | B:C Ratio | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015-16 | 2016-17 | 2017-18 | Pooled | 2015-16 | 2016-17 | 2017-18 | Pooled | 2015-16 | 2016-17 | 2017-18 | Pooled | 2015-16 | 2016-17 | 2017-18 | Pooled |
| $T_1$ RDF + water spray at pod initiation | 28146 | 29894 | 29378 | 29139 | 48205 | 53007 | 49703 | 50305 | 20059 | 23113 | 20326 | 21166 | 1.71 | 1.77 | 1.69 | 1.73 |
| $T_2$ RDF + Urea @2 % spray at pod initiation | 28026 | 30461 | 29458 | 29315 | 44916 | 60736 | 49996 | 51883 | 16890 | 30275 | 20538 | 22568 | 1.60 | 1.99 | 1.70 | 1.76 |
| $T_3$ RDF + DAP @2 % spray at pod initiation | 28591 | 31287 | 30747 | 30208 | 51558 | 70266 | 68709 | 63511 | 22967 | 38979 | 37961 | 33302 | 1.80 | 2.25 | 2.23 | 2.09 |
| $T_4$ RDF + MOP @0.5 % at pod initiation | 28238 | 30882 | 30043 | 29721 | 46682 | 65311 | 58712 | 56902 | 18444 | 34429 | 28668 | 27181 | 1.65 | 2.11 | 1.95 | 1.91 |
| $T_5$ RDF+19:19:19(NPK) @2 % at pod initiation | 29583 | 32051 | 30911 | 30848 | 52515 | 67478 | 60236 | 60077 | 22932 | 35427 | 29326 | 29228 | 1.78 | 2.11 | 1.95 | 1.94 |
| $T_6$ RDF+Molybdenum @ 0.5per cent at pod initiation | 39608 | 43006 | 41912 | 41509 | 38360 | 69862 | 58583 | 55601 | -1248 | 26856 | 16670 | 14093 | 0.97 | 1.62 | 1.40 | 1.33 |
| $T_7$ RDF+Boron @ 0.5 % at pod initiation | 28711 | 31427 | 30701 | 30280 | 47692 | 67161 | 61941 | 58931 | 18981 | 35734 | 31240 | 28652 | 1.66 | 2.14 | 2.02 | 1.94 |
| $T_8$ RDF+chelated Zinc@ 0.5 % at pod initiation | 29964 | 32917 | 31564 | 31481 | 41768 | 66026 | 50134 | 52643 | 11805 | 33109 | 18570 | 21161 | 1.39 | 2.01 | 1.59 | 1.66 |
| $T_9$ RDF only | 27138 | 29672 | 28923 | 28578 | 36255 | 55554 | 48829 | 46879 | 9116 | 25882 | 19905 | 18301 | 1.34 | 1.87 | 1.69 | 1.63 |
| SE(m) + | — | — | — | — | 2985 | 2857 | 3721 | 1657 | 2985 | 2857 | 3721 | 1657 | — | — | — | — |
| CD at 5% | — | — | — | — | 8949 | 8565 | 11155 | 4967 | 8949 | 8565 | 11156 | 4967 | — | — | — | — |

Urea = Rs 6 $kg^{-1}$, DAP = Rs. 26 $kg^{-1}$, MOP = Rs. 17.32 $kg^{-1}$, 19:19:19 = Rs. 120 $kg^{-1}$, Mo = Rs. 4000 $kg^{-1}$, Boron = Rs. 480 $kg^{-1}$, Zinc = Rs. 760 $kg^{-1}$

per ha were found in treatment of RDF + DAP @ 2 per cent at pod initiation (Rs. 63511 and 33302, respectively). but found at par with treatment of foliar spray of boran and 19:19:19 fertilizer grade along with RDF (Table 6).

The highest B:C ratio (2.09) was recorded in RDF + DAP @2 per cent spray at pod initiation .

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# Effect of Manures and Fertilizers on Nutrient Uptake by Chickpea (*Cicer arietinum* L.) and Soil Nutrient Status Under Irrigated Condition

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## ABSTRACT

A field experiment was conducted during *rabi* season, 2016-17 at the Research Farm of All India Coordinated Research Project on Integrated Farming System, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MS) with an objective to study the effect of organic manures and fertilizers on nutrient uptake by chickpea (*Cicer arietinum* L.) and soil nutrient status under irrigated condition. Result revealed that the total uptake of N (104.73 kg ha$^{-1}$), P (22.16 kg ha$^{-1}$) and K (84.34 kg ha$^{-1}$), respectively,were recorded significantly highest in 100 per cent N (RDF) + 200 per cent PandK (through organic fertilizers) which was found at par with 100 per cent N (RDF) + 150 per cent P&K (through organic fertilizers) and superior over the rests.Whereas, the available Nitrogen (235kg ha$^{-1}$), P (23 kg ha$^{-1}$) and K (377 kg ha$^{-1}$) was noticed with the application of 100 per cent N (RDF) + 200 per cent P&K (through organic fertilizers).

Pulses are major and cheaper source of protein particularly for vegetarians and contribute about 14 per cent of Indian diet. Their inclusion as main, catch, cover, green manure and intercrop rotation in farming system is found all over world to keep the soil alive and productive as they have the ability to fix the atmospheric nitrogen.Pulses are the wonderful gift of nature having unique ability of biological nitrogen fixation, deep root system, mobilization of insoluble soil nutrients and bringing changes in soils physical properties make them known as 'soil fertility restorer'. They fix and utilize atmospheric nitrogen and add up to the 30 kg N ha$^{-1}$ to the soil. They have been valued as food, feed and fodder.

Fertilizer feeds the world through feeding the soils and in turns plants, no country in the world has been able to increase agricultural productivity without expanding the use of mineral fertilizers. In India, contribution towards increase in food grain production is estimated to be 50 per cent.

The heavy fertilization policy has an adverse effect on the soil and environment which leads to heavy pollution. Integrated nutrient management is the maintenance or the adjustment of soil fertility and plant nutrient supply at an optimum level to sustain the desired crop productivity. In crop production, nutrient availability from organic fertilizer has been recognized for many centuries. Recently there has been a renewed interest in the use of organic fertilizer. This interest is attributed to concerns for maintaining sustainable agricultural production while preserving the environment.

In view of the above, the present investigation was undertaken to study the "Effect of manures and fertilizers on nutrient uptake by chickpea and soil nutrient status under irrigated condition".

## MATERIAL AND METHODS

The field selected for the experimentation was fairly uniform and leveled. Soil of experimental plot was inceptisol with clay content (58.3 %). It was low in available nitrogen (208 kg ha$^{-1}$) and phosphorous (18 kg ha$^{-1}$), moderate in organic carbon (5.8 g kg$^{-1}$), high in available potassium (352 kg ha$^{-1}$) and slightly alkaline (7.7) in reaction. The total rainfall recorded from October, 2016 to February, 2017 during crop growing season was 91.0 mm received in 5 rainy days as against normal rainfall of 102.6 mm and total rainy days of 7.2. Bright sunshine hours temperature, wind speed were lower than normal that helped the crop to utilize available soil moisture for longer period and kept the evaporation losses less which favored the crop growth. The experiment was laid out in randomized block design with eight treatments and three replications. The crop variety was JAKI-9218 sown at the row spacing of 30 cm distance. The treatment comprising at $T_1$- 100 per cent NPK (RDF) through chemical fertilizers, $T_2$-100 per cent N + 50 per cent P & K (RDF) + 50 per cent

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P & K (through organic fertilizers), $T_3$-100 per cent N (RDF) + 100 per cent P and K (through organic fertilizers), $T_4$-100 per cent N (RDF) + 150 per cent P & K (through organic fertilizers), $T_5$- 100per cent N (RDF) + 200 per cent P and K (through organic fertilizers), $T_6$- 100 per cent N and P (RDF) + 100 per cent K (through organic fertilizers), $T_7$- 100 per cent N and P (RDF) + 150per cent K (through organic fertilizers) and $T_8$- 100 per cent N and K (RDF) + 100 per cent P (through organic fertilizers). The recommended dose of fertilizers for chickpea was 25 + 50 + 30 NPK kg $ha^{-1}$. The organic fertilizers used for the experiment, by keeping the constant recommended dose of nitrogen for all the treatments and applied through chemical fertilizer only. The organic phosphatic fertilizer (pre- mixture) contains rock phosphate, compost, leaf extract of banyan, bermuda, kokum and Tulsi. The pre-mixture contents 10.42 per cent phosphate, 0.43 per cent nitrogen, 7.87 per cent organic carbon, having 18.30 C: N ratio and 25 per cent moisture by weight. While, potassic fertilizer (pre- mixture) contains ash, compost and leaf extract of banyan, bermuda, kokum and tulsi. The pre-mixture contents 10 per cent potash, 15 per cent potassium humate& 7.48 per cent organic carbon. All the fertilizers and time to time field operations were carried out in the experiment as per the treatments and University recommended package of practice.

## RESULTS AND DISCUSSION

**Uptake of nutrients by chickpea**

**Uptakeof Nitrogen**

Significantly highest nitrogen uptake in seed (69.55 kg $ha^{-1}$) was observed in 100 per cent N (RDF) + 200per cent P&K (through organic fertilizers) which was found at par with 100per cent N (RDF) + 150 per cent P&K (through organic fertilizers) and 100 per cent N (RDF) + 150 per cent K (through organic fertilizers) and superior over rests (Table1). While, treatment $T_3$(100 % N (RDF) + 100 per cent P and K (through organic fertilizers) was found significantly better than other treatments but comparable with treatment $T_6$ (100 % N and P (RDF) + 100 % K (through organic fertilizers).Whereas,lower values of nitrogen

**Table 1: NPK uptake in seed and straw of chickpea as influenced by different treatments**

| Symbol | Treatment | Total NPK uptake by chickpea (kg $ha^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Seed | Straw | Total N | Seed | Straw | Total P | Seed | Straw | Total K |
| $T_1$ | 100 % NPK (RDF) through chemical fertilizers | 35.68 | 26.72 | 62.40 | 4.68 | 6.80 | 11.48 | 17.70 | 33.25 | 50.95 |
| $T_2$ | 100 % N + 50 % P and K (RDF) + 50 % P and K (through organic fertilizers) | 37.84 | 24.40 | 62.24 | 5.39 | 7.22 | 12.61 | 19.45 | 32.77 | 52.22 |
| $T_3$ | 100 % N (RDF) + 100 % P and K(through organic fertilizers) | 60.63 | 26.38 | 87.01 | 8.43 | 8.79 | 17.22 | 29.94 | 36.48 | 66.42 |
| $T_4$ | 100 % N (RDF) + 150 % P and K(through organic fertilizers) | 67.35 | 34.01 | 101.36 | 9.89 | 11.69 | 21.58 | 33.49 | 47.57 | 81.06 |
| $T_5$ | 100 % N (RDF) + 200 % P and K (through organic fertilizers) | 69.55 | 35.18 | 104.73 | 10.23 | 11.93 | 22.16 | 34.71 | 49.63 | 84.34 |
| $T_6$ | 100 % N and P (RDF) + 100 % K (through organic fertilizers) | 55.88 | 25.32 | 81.20 | 7.49 | 8.83 | 16.32 | 27.90 | 38.17 | 66.07 |
| $T_7$ | 100 % N and P (RDF) + 150 % K (through organic fertilizers) | 63.48 | 27.50 | 90.98 | 9.02 | 9.63 | 18.65 | 31.23 | 41.01 | 72.24 |
| $T_8$ | 100 % N and K (RDF) + 100 % P (through organic fertilizers) | 41.08 | 23.06 | 64.14 | 5.66 | 7.64 | 13.30 | 20.62 | 32.57 | 53.19 |
| | SE (m) ± | 2.01 | 1.52 | - | 0.80 | 0.67 | - | 1.12 | 1.98 | - |
| | CD @5 % | 6.10 | 4.62 | - | 2.43 | 2.04 | - | 3.39 | 6.02 | - |

uptake by seed was recorded in 100 per cent NPK applied through chemical fertilizers.The beneficial effect of organic fertilizers might be due to their role in adequate nutrient supply, enhanced mobilization of nutrients, activation of beneficial soil microbes, biological N- fixation and improved physical conditions of soil which resulted in better root establishment, better translocation of absorbed nutrients from soil and its translocation to plant and seed and ultimately increased content of nitrogen. The results are in conformity of Dalvi (2011).

However, nitrogen uptake in straw was noticed significantly higher (35.18 kg ha$^{-1}$) in treatment 100 per cent N (RDF) + 200 per cent P and K (through organic fertilizers) which was found at par with 100 per cent N (RDF) + 150 per cent P and K (through organic fertilizers) and superior over rest of the treatments. While, remaining treatments were at par among each other. The lower value for phosphorous uptake in straw was noted in treatment $T_8$ (100 % N and K (RDF) + 100 per cent P (through organic fertilizers).

**Uptakeof Phosphorous**

Significantly highest phosphorus uptake in seed (10.23 kg ha$^{-1}$) and straw (11.93 kg ha$^{-1}$) was observed in 100per cent N (RDF) + 200per cent P and K (through organic fertilizers) but observed at par with 100per cent N (RDF) + 150 per cent P and K (through organic fertilizers), 100 per cent N and P (RDF) + 150 per cent K(through organic fertilizers) and 100per cent N (RDF) + 100 per cent P and K (through organic fertilizers).Phosphorus uptake in straw was noted higherwith the application of 100 per cent N (RDF) + 200 per cent P and K (through organic fertilizers) and at par with 100per cent N (RDF) + 150 per cent P and K (through organic fertilizers) and superior over rest of treatments (Table1). Remaining treatments were found at par with each other. The increase in uptake of phosphorous might be due to enhanced physiological processes within the plant system which resulted in the increased absorption of phosphorus by chickpea and thereby, translocation of phosphorus might have occurred and get accumulated in straw which resulted in higher P uptake. These results are in close confirmation of Neenu *et al.* (2014).

**Uptake of Potassium**

Significantly highest potassium uptake in seed (34.71 kg ha$^{-1}$) and straw (49.63 kg ha$^{-1}$) were observed in 100per cent N (RDF) + 200 per cent P and K (through organic fertilizers)which was at par with 100 per cent N (RDF) + 150 per cent P and K (through organic fertilizers) and significantly superior over rest of the treatments (Table). The increase in uptake of potassium might be due to the initial higher availability of potassium in experimental soil, mobile nature of K and high root biomass resulted higher absorption of potassium by plant. These results are in line of the findings of Das *et al.* (2016).

**Soil nutrient statusof soil after crop harvest**

**Available nitrogen**

The available nitrogen in soil was significantly improved by the different combination of organic and

**Table 2: Nutrient status in soil after harvest of crop(kg ha$^{-1}$) as influenced by different treatments**

| Symbol | Treatment | Available N | Available P | Available K |
|---|---|---|---|---|
| $T_1$ | 100% NPK (RDF) through chemical fertilizers | 210 | 15 | 342 |
| $T_2$ | 100% N + 50% P & K (RDF) + 50% P & K (through organic fertilizers) | 211 | 16 | 351 |
| $T_3$ | 100% N (RDF) + 100% P & K(through organic fertilizers) | 222 | 19 | 359 |
| $T_4$ | 100% N (RDF) + 150% P & K(through organic fertilizers) | 231 | 22 | 364 |
| $T_5$ | 100% N (RDF) + 200% P & K (through organic fertilizers) | 235 | 23 | 377 |
| $T_6$ | 100% N & P (RDF) + 100% K (through organic fertilizers) | 219 | 17 | 355 |
| $T_7$ | 100% N & P (RDF) + 150% K (through organic fertilizers) | 228 | 21 | 365 |
| $T_8$ | 100% N & K (RDF) + 100% P (through organic fertilizers) | 218 | 17 | 348 |
| | Se (m) ± | 2.69 | 1.25 | 3.77 |
| | CD @5% | 8.17 | 3.79 | 11.43 |

inorganic fertilizers (Table 2). The highest available nitrogen (235kg $ha^{-1}$) was recorded in treatment 100per cent N (RDF) + 200 per cent P and K (through organic fertilizers) but found at par with 100 per cent N (RDF) + 150 per cent P and K ( through organic fertilizers) and 100 per cent N and P (RDF) + 150 per cent K (through organic fertilizers). The application of 100 per cent N (RDF) + 100 per cent P and K(through organic fertilizers) recorded significantly higher available Nin soil followed by treatment 100 per cent N & P (RDF) + 100 per cent K (through organic fertilizers) and 100 per cent N and K (RDF) + 100 per cent P (through organic fertilizers). Whereas, the lower nitrogen statusin soil was noticed in treatment 100 per cent NPK (RDF) through chemical fertilizers closely followed by treatment100 per cent N + 50 per cent P and K (RDF) + 50 per cent P and K (through organic fertilizers). The higher values of available nitrogen might be due to activity of microorganism in soil which helped to fix atmospheric nitrogen. Available N content further increased might be due to the combined application of organic fertilizers with inorganic one. Similar results were obtained by Chandrashekhar *et al.* (2014).

**Available phosphorous**

Available phosphorus in soil was significantly improved by different organic and inorganic fertilizers (Table 2). The highest available phosphorous (23 kg $ha^{-1}$) was observed in treatment 100per cent N (RDF) + 200 per cent PandK (through organic fertilizers) and statistically it was comparable with 100 per cent N (RDF) + 150 per cent Pand K ( through organic fertilizers), 100per cent N and P (RDF) + 150 per cent K(through organic fertilizers) and 100 per cent N (RDF) + 100 per cent P and K (through organic fertilizers). The remaining treatments were on par with each other. Available phosphorus increased with increasing levels of fertilizers in soil and it was increased in soil after harvest of crop. These results are in agreement with the findings of Thakur *et al.* (2011).

**Available potassium**

Significantly higher available potassium (377 kg $ha^{-1}$) in soil was observed in 100 per cent N (RDF) + 200 per cent P and K (through organic fertilizers) and lower in100 per cent NPK (RDF) applied through chemical fertilizers (Table 2). Treatment100 per cent N and P (RDF) + 150 per cent K (through organic fertilizers) recorded significantly higher available potassium in soil and observed comparable with treatments of 100 per cent N (RDF) + 150 per cent P and K(through organic fertilizers), 100 per cent N (RDF) + 100 per cent P and K(through organic fertilizers) and 100 per cent N and K (RDF) + 100 per cent P (through organic fertilizers)and rest of treatments were found on par with each other. Organic fertilizers found beneficial than inorganic fertilizers. These results are in agreement with the findings of Vidyavathi *et al.* (2012).

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# Assessment of Spatial Variability of Major and Micro Nutrients in Soils of Akola District of Maharashtra, India

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## ABSTRACT

Georeferenced surface soil samples from seven tehsils in Akola district of Maharashtra were collected using Global Positioning System (GPS) to study the variability in availability of major and micro nutrients. The stratified random sampling method was used to locate the sampling villages in each tehsils. The fertility maps were prepared using Geographical Information System for each nutrient. The results revealed that pH, EC, $CaCO_3$ and OC of soils collected across different tehsils of Akola district varied from 6.91 to 8.89, 0.11 to 0.99 dS $m^{-1}$, 1.25 to 31.87 per cent and 1.20 to 11.20 g $kg^{-1}$, respectively. Whereas available N, P, K and S in soils ranged from 94.3 to 305.5 kg $ha^{-1}$, 1.06 to 16.71 kg $ha^{-1}$, 63.6 to 985.6 kg $ha^{-1}$ and 1.03 to 56.94 mg $kg^{-1}$, respectively. The DTPA-Zn, Fe, Cu and Mn in soil of Akola district ranged from 0.11 to 6.09 mg $kg^{-1}$, 1.15 to 94.44 mg $kg^{-1}$, 0.14 to 11.11 mg $kg^{-1}$and1.39 to 62.17 mg $kg^{-1}$, respectively. The $CaCl_2$-B in soils of all the tehsils ranged from 0.17 to 1.00 mg $kg^{-1}$. The low nutrient indices were found in respect to nitrogen (1.03), phosphorus (1.00) and zinc (1.36), medium for sulphur (1.68), potassium (1.87), boron (1.71) and iron (1.79) and high for copper (2.83) and manganese (2.61). The results obtained in the present study clearly showed a large variability in physio-chemical properties of soil across the Akola district. This information could aid in decision making for application of plant nutrients and selection of cropping sequence for higher monetary returns to the farmers.

Information technology has provided tools *viz.,* Global Positioning System (GPS) which helps in collecting a systematic set of georeferenced soil samples and generating the spatial data about the distribution of nutrients through Geographical Information System (GIS). Understanding of spatial variability and distribution of soil properties is critical for farmers attempting to increase nutrients use efficiency and crop productivity. Application of fertilizers on the basis of soil characteristics associated with fertilizers recommendation may aid in minimizing the fertilizers input without any yield loss (Yadav *et al.,* 2018). The information about spatial variability in physio-chemical properties of soil had great importance in the selection of crops and cropping system and also extent the ideas about prevailing management practices (Weindorf and Zhu, 2010 and Liu *et al*., 2013). Spatial variability in pH, organic matter, total and available NPK and micronutrients has been studied by various researchers under contrasting soil and management systems to refine and implement the site-specific management (Franzen *et al.*, 2002 and Li *et al.*, 2011). Imbalanced and inadequate use of fertilizers coupled with low use efficiency of other inputs led to decline in the response efficiency of chemical fertilizer nutrients under intensive agriculture in recent years. Micronutrients are important for maintaining soil health and increasing use efficiency of major nutrients and ultimately the crop productivity. The deficiency of micronutrients has become major constraint in sustainable crop productivity of soils and hence there is need to know the spatial variability of nutrients of the soil (Katkar *et al.,* 2018). Keeping this in view, the present investigation was undertaken to assess the status of major and micronutrients in soils and to identify and delineate areas of nutrient deficiencies in Akola district of Maharashtra.

## MATERIAL AND METHODS

### Description of the study area

Akola district of Maharashtra is situated between 19° 44' to 21° 16' North latitude and 76° 38' to 77° 44' East longitude. Total geographical area of the district is 5,41,700 ha and is divided into seven tehsils (Telhara, Akot, Balapur, Akola, Murtizapur, Patur and Barshitakali).

### Soil sampling and analysis

GPS based four hundred ninety eight surface soil samples (0-20 cm) were collected from 83 villages across

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all the seven tehsils of Akola district. The sampling villages were selected using stratified random method. Six farmers from each village were selected based on land holdings. The soil samples were processed and analyzed for pH and EC in soil:water suspensions (1:2.5 w/v) as described by Jackson (1973). Organic carbon was determined by wet oxidation method described by Walkley and Black (Nelson and Sommers, 1982) and free $CaCO_3$ was determined by Rapid titration method (Piper, 1966). Available N was estimated by alkaline permanganate method (Subbiah and Asija, 1956), available P by Bray's method (Bray and Kurtz, 1945), available K by ammonium acetate extraction method (Jackson, 1967) and available S was estimated by turbidimetric method (Chesnin and Yien, 1951). Soil samples were extracted with 0.005 M diethylene triamine penta acetic acid (DTPA) for estimation of available Zn, Fe, Cu and Mn using Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978). Available boron was determined by 0.01 M $CaCl_2$ extract with Azo-methine method (Berger and Troug, 1939). The nutrient indices were calculated by using the formula given by Parker *et al.* (1951) and categorized into low (<1.66), medium (1.66 – 2.33) and high (> 2.33).

$$\text{Nutrient index} = \frac{\text{per cent samples low x 1 + per cent samples medium x 2 + per cent samples high x 3}}{100}$$

The major and micronutrients were categorized as low, medium and high which is followed in maharashtra state (Table 1).

## RESULTS AND DISCUSSION

**Soil properties** :

The pH of soils in Akola district was recorded neutral to alkaline (6.91 – 8.89) (Table 2). The highest pH was observed in Balapur tehsil (8.89) and lowest in Patur tehsil (6.91). Maximum soil samples were found slightly tomoderately alkaline in nature. All the soils were non-saline (0.11 to 0.99 dS $m^{-1}$) in nature and suitable for healthy plant growth with a mean value of 0.34 dS $m^{-1}$ which was in normal range (< 1 dS $m^{-1}$). The organic carbon content in soils ranged from 1.20 to 11.20 g $kg^{-1}$. Calcium carbonate content in soils of the district varied from 1.25 to 31.87 per cent, which indicated, the soils are calcareous in nature. High calcium carbonate is harmful; it reduces the

**Table 1. Categorization of soil parameters and nutrients**

| S.N. | Parameters | Low | Medium | High |
|---|---|---|---|---|
| 1 | pH (1:2.5) | <6.5 (Acidic) | 6.5-7.5 (Neutral) | >7.5 (Alkaline) |
| 2 | EC (dS $m^{-1}$) | <1.0 | 1-2 | >2.0 |
| 3 | O.C. (g $kg^{-1}$) | <4.0 | 4-8 | >8.0 |
| 4 | $CaCO_3$ (per cent) | <3.0 | 3-8 | >8.0 |
| 5 | N (kg $ha^{-1}$) | <280 | 280-560 | >560 |
| 6 | P (kg $ha^{-1}$) | <14 | 14-28 | >28 |
| 7 | K (kg $ha^{-1}$) | <150 | 150-250 | >250 |
| 8 | S (mg $kg^{-1}$) | <10.0 | 10-20 | >20.0 |
| 9 | Zn (mg $kg^{-1}$) | <0.60 | 0.6-1.80 | >1.80 |
| 10 | Fe (mg $kg^{-1}$) | <4.50 | 4.50-18.0 | >18.0 |
| 11 | Cu (mg $kg^{-1}$) | <0.20 | 0.20-0.80 | >0.80 |
| 12 | Mn (mg $kg^{-1}$) | <2.0 | 2.0-8.0 | >8.0 |
| 13 | B (mg $kg^{-1}$) | <0.50 | 0.50-1.0 | >1.0 |
| 14 | Mo (mg $kg^{-1}$) | <0.10 | 0.10-0.40 | >0.40 |

(Source : Dr. PDKV, Akola)

concentration of micronutrient cations in soils to such a level that the sensitive plant suffers from deficiency of micronutrients (Deb *et al.* 2009). The higher calcium carbonate content was noticed in Murtizapur,Akola, Balapur, and Akot tehsils. Organic carbon deficiency was recorded in 35.1 per cent soil samples across the district. The high temperature during summer and non-addition of organic matter regularly might have shown its deficiency in Akola district. The soil samples collected from tehsils Telhara, Murtizapur, Akot and Barshitakali showed organic carbon deficiency in 53.7, 47.6, 44.0 and 38.9 per cent samples respectively.

**Major nutrients status**

Available nitrogen was noticed in the range of 94.3 to 305.5 kg ha$^{-1}$,which showed widespread deficiency (Table 3). The deficiency of available nitrogen might be due to very less addition of organic manures and heavy uptake under intensive cultivation of improved high yielding varieties of different crops. Available P varied from very low to medium (1.06 – 16.71 kg ha$^{-1}$) indicating 99.6 per cent deficiency in almost all the tehsils. The deficiency of available P ascribed to its fixation in the form of aluminum and iron phosphate due to slightly acidic nature of soil. The available K ranged from 63.6 to 985.6 kg ha$^{-1}$ and 28.71 per cent samples were found deficient while 56.23 per cent samples were found medium. This could be attributed to more intense weathering, release of labile K from organic residues, application of K fertilizers and upward translocation of K from lower depths along with capillary rise of ground water (Sharma and Anil Kumar, 2003). During post green revolution era, the available potassium was considered very high in many soils. The recent trends indicated that slight potassium deficiency occurred, showing response to its addition. The available sulphur varied from very low to very high (1.03 to 56.94 mg kg$^{-1}$) with 53.21 per cent deficiency whereas 27.71 per cent samples were found medium (Table 3). The intensive cultivation of crops and application of fertilizers devoid of sulphur might be depleting the sulphur from soil.The application of balanced nutrition to the crops under intensive cultivation is essential for maintaining the soil fertility and sustainable productivity.

**Micronutrients status**

Data pertaining to DTPA-Zn in soils of Akola district showed that DTPA-Zn of Akola district as a whole, varied from 0.11 to 6.09 mg kg$^{-1}$ (Table 4) indicating 70.5 per cent deficiency, whereas 23.9 per cent samples of available Zn were noticed in medium category showing widespread deficiency of zinc. The highest deficiency of zinc was observed in Akola tehsil followed by Murtizapur, Balapur and Barshitakali. The availability of micronutrient cations is generally low in alkaline soils and crops grown on these soils suffer from hidden hunger (Malewar, 2005). Major crops grown in these tehsils are cotton, soybean, pigeonpea, sorghum, pulses (blackgram, greengarm and chickpea), pearl millet, maize, safflower, sunflower and sesamum etc., and their intensive cultivation might have mined the zinc along with N, P and K over a long period. All the tehsils indicated wide spread zinc deficiency in Akola district. The deficiency of nutrients creates imbalance in soils which results into nutritional stress in plants. High pH and high contents of $CaCO_3$ can fix Zn in the soil and results in reduction of available zinc (Hafeez *et al.,*2013).

DTPA-Fe content showed wide variation (1.15 to 94.44 mg kg$^{-1}$) in the soils of Akola district. Considering the soils having < 4.5 mg kg$^{-1}$ as low, 4.5 to 18.0 mg kg$^{-1}$ as medium and > 18.0 mg kg$^{-1}$ as high in iron status, the distribution of soil samples under these categories was 31.7, 57.1 and 11.2 per cent, respectively indicating that the soils are becoming deficient in iron followed by zinc. Shukla *et al.*(2016) reported low Fe content in forage and food grains produced in arid and semi-arid regions is attributed to acute Fe deficiency in soils (85per cent in Rajasthan, 23 per cent in Gujrat, 22 per cent in Haryana and 21per cent in Maharashtra). Patil *et al.* (2004) reported 40.0 and 34.7 percent soils deficient in zinc and iron respectively in Vidarbha.

The DTPA extractable Cu in the soils of Akola district ranged from 0.14 to 11.11 mg kg$^{-1}$ (Table 4). Patil and Sonar (1994) reported available Cu in range of 0.58 to 1.7 mg kg$^{-1}$in swell-shrink soils of Maharashtra. The majority of soils in Akola district were found sufficient in Cu content.

The DTPA-Mn status of soils ranged from 1.39 to 62.17 mg kg$^{-1}$ (Table 4). Gajbhe *et al.* (1976) reported available Mn content in surface soils of Marathwada ranged from 13.3 to 65.20 mg kg$^{-1}$. Soils of Akola district

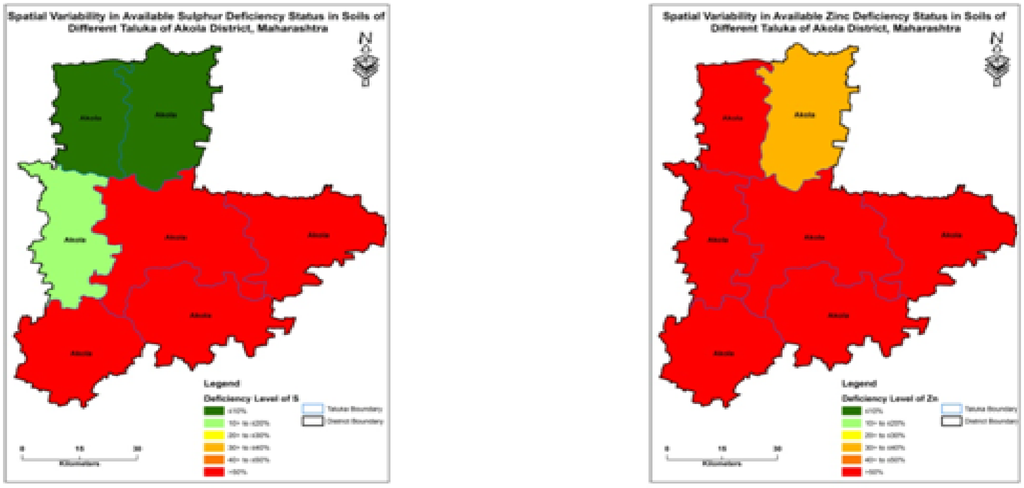


**Fig. 1. Spatial variability of available S and Zn in soils of Akola district of Maharashtra**

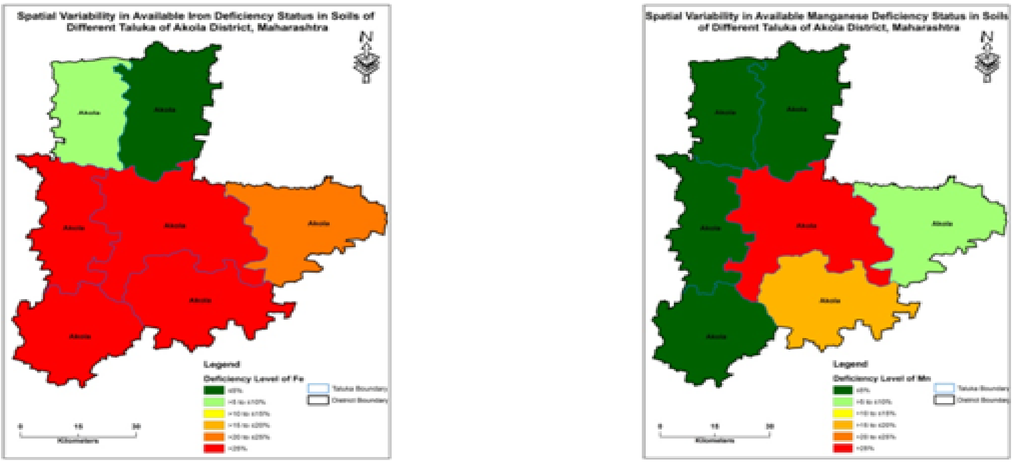


**Fig. 2. Spatial variability of available Fe and Mn in soils of Akola district of Maharashtra**

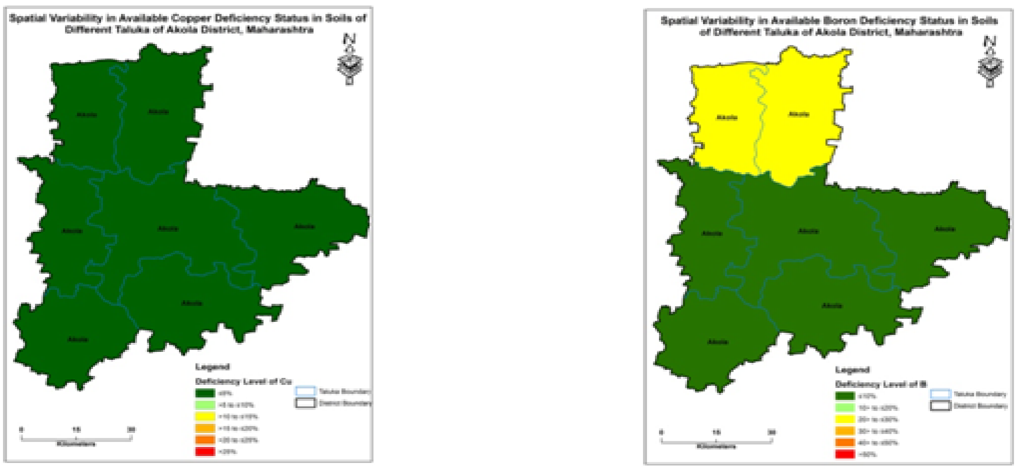


**Fig. 3. Spatial variability of available Cu and Bo in soils of Akola district of Maharashtra**

**Table 2. Chemical properties of soils in Akola district**

| S. N. | Tehsils | pH (1:2.5) | | EC (dS $m^{-1}$) | | $CaCO_3$ (%) | | Organic carbon (g $kg^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| 1 | Telhara | 7.25 - 8.88 | 8.11 | 014 - 0.98 | 0.33 | 1.25-16.25 | 9.02 | 1.45 - 9.47 | 4.32 |
| 2 | Akot | 7.23 - 8.71 | 7.96 | 0.11 - 0.80 | 0.34 | 2.12-21.12 | 11.29 | 1.20 - 9.64 | 4.64 |
| 3 | Balapur | 7.50 - 8.89 | 8.03 | 0.11 - 0.71 | 0.30 | 4.50-27.37 | 13.85 | 1.39 - 9.21 | 5.88 |
| 4 | Akola | 7.21 - 8.63 | 7.91 | 0.11 - 0.67 | 0.36 | 2.37-27.75 | 13.99 | 1.24 - 9.90 | 5.86 |
| 5 | Murtizapur | 7.20 - 8.71 | 7.93 | 0.11 - 0.99 | 0.35 | 2.00-31.87 | 14.27 | 1.47 - 9.10 | 4.30 |
| 6 | Patur | 6.91 - 8.04 | 7.51 | 0.23 - 0.87 | 0.39 | 2.62-19.25 | 8.95 | 2.85 - 9.96 | 7.17 |
| 7 | Barashitakali | 7.08 - 8.57 | 7.73 | 0.16 - 0.81 | 0.34 | 2.38-25.87 | 11.29 | 1.40 - 11.20 | 5.05 |
| | **Akola district** | **6.91 -8.89** | **7.89** | **0.11 - 0.99** | **0.34** | **1.25-31.87** | **12.11** | **1.20 - 11.20** | **5.22** |

**Table 3. Macronutrients status of soils in Akola district**

| S. N. | Tehsils | N (kg $ha^{-1}$) | | P (kg $ha^{-1}$) | | K (kg $ha^{-1}$) | | S (mg $kg^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Range | PSD | Range | PSD | Range | PSD | Range | PSD |
| 1 | Telhara | 94.8 - 305.5 | 81.5 | 2.33 - 16.71 | 98.1 | 134.4 - 481.6 | 1.85 | 9.87 - 39.55 | 1.86 |
| 2 | Akot | 94.8 - 284.4 | 98.8 | 2.13 - 15.80 | 98.8 | 112.0 - 694.4 | 14.28 | 8.80 - 56.94 | 4.76 |
| 3 | Balapur | 94.3 - 273.9 | 100.0 | 3.63 - 8.67 | 100.0 | 100.8 - 616.0 | 33.34 | 4.05 - 41.52 | 16.66 |
| 4 | Akola | 105.4 - 252.3 | 100.0 | 2.01 - 9.72 | 100.0 | 67.2 - 560.0 | 33.34 | 1.03 - 31.11 | 96.08 |
| 5 | Murtizapur | 94.8 - 263.4 | 100.0 | 2.04 - 10.49 | 100.0 | 67.2 - 403.2 | 28.57 | 1.71 - 28.26 | 80.95 |
| 6 | Patur | 115.9 - 263.3 | 100.0 | 1.15 - 9.59 | 100.0 | 67.2 - 481.6 | 20.0 | 1.03 - 23.00 | 85.42 |
| 7 | Barashitakali | 115.8 - 284.5 | 98.6 | 1.06 - 13.51 | 100.0 | 63.6 - 985.6 | 41.67 | 1.84 - 42.55 | 61.11 |
| **Akola district** | | **94.3 - 305.5** | **97.6** | **1.06 - 16.71** | **99.6** | **63.6 - 985.6** | **28.71** | **1.03 - 56.94** | **53.21** |

**PSD – Percent sample deficient**

**Table 4.Micronutrients status (mg kg$^{-1}$) of soil in Akola district**

| S. N. | Tehsils | Zn | | FE | | CU | | MN | | B | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RANGE | PSD | RANGE | PSD | RANGE | PSD | RANGE | PSD | RANGE | PSD |
| 1 | TELHARA | 0.12 - 4.40 | 64.8 | 3.17 - 13.54 | 5.5 | 1.09 - 11.11 | 0 | 3.92 - 32.56 | 0 | 0.38 – 0.73 | 19.0 |
| 2 | AKOT | 0.16 - 6.09 | 29.8 | 1.82 - 94.44 | 3.6 | 0.91 - 6.83 | 0 | 5.41 - 62.17 | 0 | 0.29 – 0.70 | 28.5 |
| 3 | BALAPUR | 0.11 - 2.00 | 85.2 | 1.30 - 18.58 | 25.9 | 0.96 - 5.76 | 0 | 3.54 - 39.80 | 0 | 0.53 – 1.00 | 4.8 |
| 4 | AKOLA | 0.11 - 2.57 | 88.2 | 1.17 - 14.78 | 57.8 | 0.14 - 4.40 | 4.9 | 1.39 - 24.0 | 6.0 | 0.17 – 0.75 | 14.3 |
| 5 | MURTIZAPUR | 0.15 - 6.00 | 86.9 | 1.42 - 37.66 | 23.8 | 0.18 - 5.28 | 1.2 | 2.64 - 23.78 | 0 | 0.38 – 0.79 | 14.3 |
| 6 | PATUR | 0.39 - 1.25 | 52.1 | 1.15 - 14.50 | 39.6 | 0.30 - 4.86 | 0 | 4.50 - 15.88 | 0 | 0.35 – 0.79 | 23.8 |
| 7 | BARASHITAKALI | 0.15 - 1.67 | 79.2 | 1.36 - 35.72 | 55.6 | 0.24 - 7.82 | 0 | 2.05 - 28.58 | 0 | 0.40 – 0.69 | 4.8 |
| | **AKOLA DISTRICT** | **0.11 - 6.09** | **70.5** | **1.15 - 94.44** | **31.7** | **0.14–11.11** | **1.2** | **1.39 - 62.17** | **1.2** | **0.17 – 1.00** | **15.6** |

**PSD – Percent sample deficient**

**Table 5.Nutrient index values of soil available nutrients in different tehsils of Akola district**

| S.N. | Name of the tehsils | No. of samples | Nutrient Index | | | | | | | | | ValueFertility rating | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | N | P | K | S | Zn | Fe | Cu | Mn | B | N | P | K | S | Zn | Fe | Cu | Mn | B |
| 1 | Telhara | 54 | 1.18 | 1.01 | 2.44 | 2.42 | 1.14 | 1.94 | 2.65 | 2.90 | 1.80 | L | L | H | H | L | M | H | H | M |
| 2 | Akot | 84 | 1.01 | 1.01 | 2.03 | 2.44 | 1.91 | 2.33 | 3.0 | 2.94 | 1.80 | L | L | M | H | M | H | H | H | M |
| 3 | Balapur | 54 | 1.00 | 1.0 | 1.79 | 1.80 | 1.17 | 1.78 | 3.0 | 2.65 | 1.85 | L | L | M | M | L | M | H | H | M |
| 4 | Akola | 102 | 1.00 | 1.0 | 1.73 | 1.05 | 1.13 | 1.42 | 2.65 | 2.03 | 1.42 | L | L | M | L | L | L | H | H | L |
| 5 | Murtizapur | 84 | 1.00 | 1.0 | 1.79 | 1.20 | 1.17 | 1.96 | 2.61 | 2.58 | 1.42 | L | L | M | L | L | M | H | H | L |
| 6 | Patur | 48 | 1.00 | 1.0 | 1.58 | 1.16 | 1.48 | 1.60 | 2.98 | 2.77 | 1.76 | L | L | L | L | L | L | H | H | M |
| 7 | Barashitakali | 72 | 1.01 | 1.0 | 1.72 | 1.73 | 1.21 | 1.53 | 2.93 | 2.43 | 1.95 | L | L | M | M | L | L | H | H | M |
| **Over all Mean** | | **498** | **1.03** | **1.0** | **1.87** | **1.68** | **1.36** | **1.79** | **2.83** | **2.61** | **1.71** | **L** | **L** | **M** | **M** | **L** | **M** | **H** | **H** | **M** |

**Low - < 1.66, Medium - 1.66 - 2.33, High - > 2.33**

were sufficient in Mn and Cu. $CaCl_2$-B in soils of all the tehsils ranged from 0.17 to 1.00 mg $kg^{-1}$. Boron deficiency was observed in 16 per cent samples while 84 per cent samples were noticed in medium category. The highest deficiency was noticed in Akot, Patur and Telhara tehsils followed by Akola and Murtizapur tehsils.

**Nutrient indices**

The nutrient indices across the Akola district ranged from1.0-1.18 for N, 1.0-1.01 for P, 1.58-244 for K, 1.05-2.44 for S, 1.13 - 1.91 for Zn, 1.42 – 2.33 for Fe, 2.61 – 3.00 for Cu, 2.03 – 2.94 for Mn and 1.42 - 1.95 for B. Notably low fertility rating was recorded for N, P and Znin most of the tehsils, high for Cu and Mn, medium for K, S, Fe and B. In nutshell, overall fertility rating for nutrients in the soils of Akola district revealed low N, P and Zn, marginal K, S, Fe and B, high Cu and Mn status. The areas where the status of nutrients are medium, may show deficiency in near future if the due care is not taken for addition of organic manures and inorganic micronutrient fertilizers based on soil testing by the cultivators in the districts for intensive cultivation of different crops (Malewar, 2005).

## CONCLUSION

The information technology based GPS-GIS technique has been found useful for systematic mapping of spatial variability of macro and micro nutrients. Among the major nutrients, nitrogen (97.6%) and phosphorus (99.6 %) was found deficient. The micronutrients viz., zinc (70.5 %), iron (31.7%) and boron (15.6%) showed deficiency. The current status of spatial variability of micronutrients in soils of Akola district will be helpful to suggest the efficient ways and methods of balanced nutrient application for enhancing the yields by using recommended quantities of organic manures and inorganic fertilizers in the areas of major and micro-nutrients deficiency.

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# Effect of Sulphur and Zinc Containing Customized Fertilizers on Onion Yield and Soil Nutrient Status in Inceptisols

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## ABSTRACT

The present investigation was conducted during *rabi*- 2016-17 to study the "Evaluation of efficacy ofsulphur and zinc containing customized fertilizers on onion yield and soil nutrient status Inceptisols" at Research Farm, Chilli and Vegetable Research Unit, Dr. PDKV, Akola. The experiment was laid out in Randomized Block Design with eleven treatments replicated thrice. The soil samples were collected, analyzed for different soil properties and availability of major and micronutrients. The results revealed that, the highest onion bulb yield was recorded with the application of balanced fertilizer dose of NPKS Zn (100:50:50:40:17.50 kg $ha^{-1}$ N, $P_2O_5$, $K_2O$, S, Zn) followed by application of recommended dose through customized fertilizer grade (12:45:00:05:01) NPKS Zn + compensation of N and K through conventional fertilizer. The recommended dose applied through grade III (12:45:00:05:01) and compensation of N and K through conventional source recorded highest onion bulb yield and availability of major and micronutrients in soil.The application of recommended dose of fertilizer (NPKS Zn) through conventional fertilizer recorded higher available nitrogen and potassium in soil after harvest of onion. Whereas, available phosphorus was recorded highest with application of recommended dose through customized grade III NPS Zn compensation of N and K through conventional fertilizer after harvest of onion. Available sulphur and zinc were found highest with the application of balanced fertilizer dose of NPKS Zn through conventional fertilizer. Thus, it can be concluded that, the balanced application of nutrients (N,P,K,S and Zn) either through conventional or customized fertilizer grades (NPS Zn) found beneficial in enhancing onion bulb yield and sustaining soil fertility.

Onion (*Allium cepa* L.) is one of the most popular bulb vegetables and commercially important vegetable worldwide. The productivity and quality of any crop depends on nutrients and environment under which it is cultivated. Although plants obtain certain quantity of nutrients from the soil, they are inadequate to meet the demand for higher production. Therefore, it is most essential to provide major, secondary and micronutrient in balanced way towards sustainable production of a crop. Sulphur is a constituent of secondary compounds viz., allin, cycloallin and thiopropanol which not only influence the taste, pungency and medicinal properties of onion but also induce resistance against pests and diseases. Sulphur is required for the synthesis of essential amino acids such as cystine (27% S), cysteine (26% S) and methionine (21% S) besides increasing allyl propyl disulphide (alkaloid) (43% S) and the capsaicin, the principle alkaloids responsible for pungency in onion and chilli (Randle and Bussard, 1993). The continuous adaptation of sulphur free fertilizer in recent years coupled with decreased atmospheric input of sulphur has lead to a marked increase in the incidence of sulphur deficiency in the crops.

Zinc play active role in plant metabolic process such as nitrogen fixation, enzyme activity and is essential for tryptophan synthesis, which is prerequisite for auxin formation, the amount of auxin decreases with zinc deficiency. Zinc deficiency decreases the plant growth when concentration of phosphorus increases in soil as well as plant. Favourable effect of zinc on plant growth is observed in many physiological process and cellular function within plant. It plays an essential role in improving plant growth through the biosynthesis of endogenous hormone which is responsible for plant growth (Hansch and Mendel, 2009).

Customized fertilizers are multi-nutrient carrier designed to contain macro and micro nutrient forms, both from inorganic and organic sources, manufactured through a systematic process satisfying the crops nutritional needs, for specific site, soil and stage validated by a scientific crop model developed by an accredited fertilizer manufacturing company. The customized fertilizer is the use of fertilizer best management practices and intended to maximize crop yields without risking the environment and human health. Application of customized fertilizers are expected to be compatible with existing farming

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systems and making them acceptable to the farmers. Adoption of such fertilizers would enhance the nutrient use efficiency which is currently 40 per cent for N, 20 per cent for P per cent 50 per cent for K, 2-5 per cent for other micronutrients. In view of above, the present investigation was undertaken to study the effect of sulphur and zinc application along with NPK on yield and fertility status of soil after harvest of onion.

## MATERIAL AND METHODS

The experiment was initiated during rabi season 2015-16 at Research Farm, Chilli and Vegetable Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The study was conducted during rabi 2016-17. The experiment was laid out in randomized block design with eleven treatments and three replications. The treatment comprised of $T_1$ -Control,$T_2$- RDF (100:50:50 kg ha$^{-1}$ N,$P_2O_5$, $K_2O$),$T_3$-RDF(100:50:50 kg ha$^{-1}$ N,$P_2O_5$, $K_2O$), along with 40 kg ha$^{-1}$ S,$T_4$- RDF S+ Zn 3.50,$T_5$- RDF + FYM @ 5 t ha$^{-1}$,$T_6$- RDF of P through NPS-1(compensation N and K through conventional fertilizers),$T_7$- RDF of P through NPS-2(compensation N and K through conventional fertilizers),$T_8$ -RDF of P through NPS Zn (compensation N and K through conventional fertilizers),$T_9$ -RDF+ Sulphur equivalent to NPS-1,$T_{10}$ -RDF + Sulphur equivalent to NPS-2,T11 -RDF + Sulphur and Zn equivalent to NPS Zn. The treatment wise bulb yield of onion was recorded. The treatment wise soil samples upto 20 cm depth were collected. The processed soil samples were analyzed for different soil properties following standard procedures; Available N by Alkaline potassium permanganate method (Subbiah and Asija, 1956).Available P by Olsen method ($NaHCO_3$, 0.5M) pH 8.5 colorimetric (Watanabe and Olsen, 1965),Available K by Neutral normal ammonium acetate using Flame photometer (Jackson,1973), Available S by Turbidimetrically ($CaCl_2$ extract) Chesnin and Yien (1951),DTPA-Zn,Fe,Mn and Cu extracted with DTPA and recorded using atomic absorption spectrophotometer (Lindsay and Norvell,1978).

## RESULTS AND DISCUSSION

**Onion Bulb yield**

The significantly highest onion bulb yield (397.75 q ha$^{-1}$) was recorded (Table1) with the combined application of recommended dose of NPKS Zn (100:50:50:40:17.50 kg ha$^{-1}$ N, $P_2O_5$, $K_2O$, S and Zn) which was found at par with recommended dose NPKS through conventional fertilizer (387.79 q ha$^{-1}$) and recommended dose grade III (12:45:00:05:01) containing NPS Zn (compensation of N and K through conventional fertilizers). Among the customized fertilizer grades, the treatment of grade III (12:45:00:05:01) recorded significantly highest onion bulb yield (382.80 q ha$^{-1}$) as compared to the treatments of grade I (19:38:00:07) and grade II (12:46:00:07). This could be attributed to the supply of balanced nutrition which led to higher onion bulb yield. Similar results were recorded by Ghotekar *et al.* (2015) and Kamble and Kathmale (2015).

**Table 1. Bulb yield of onion as influenced by various treatments**

| Treatments | | Bulb Yield (q ha$^{-1}$) |
|---|---|---|
| $T_1$ | Absolute Control | 258.86 |
| $T_2$ | RDF of NPK | 316.39 |
| $T_3$ | RDF of NPKS | 387.79 |
| $T_4$ | RDF of NPKS Zn | 397.75 |
| $T_5$ | RDF of NPK + FYM | 383.28 |
| $T_6$ | RDF of P through NPS-1( N and K through conventional fertilizers) | 381.04 |
| $T_7$ | RDF of P through NPS-2( N and K through conventional fertilizers) | 379.15 |
| $T_8$ | RDF of P through NPS Zn( N and K through conventional fertilizers) | 382.80 |
| $T_9$ | RDF of NPK + Sulphur equivalent to NPS 1 supplied in $T_6$ | 377.96 |
| $T_{10}$ | RDF of NPK + Sulphur equivalent to NPS 2 supplied in $T_7$ | 374.84 |
| $T_{11}$ | RDF of NPK + Sulphur and Zn equivalent to NPS Zn supplied in $T_8$ | 380.02 |
| | SE (m) ± | 15.20 |
| | CD at 5 % | 44.82 |

**Available major nutrients**

The soil fertility exhibits the status of soil with regard to the quantity and availability of nutrients essential for plant growth. The significantly highest available N (192.1 kg ha$^{-1}$) was recorded with recommended dose of NPKS Zn (Table 2). Among the customized fertilizers grades treatments, the treatment of grade III (12:45:00:05:01) recorded significantly highest available nitrogen (184.7 kg ha$^{-1}$) as compared to the treatment of grade I (19:38:00:07) and grade II (12:46:00:07). Among the customized grades treatments, the treatment of grade III (12:45:00:05:01) recorded significantly highest available phosphorus content (21.81 kg ha$^{-1}$) as compared to the treatment of grade I (19:38:00:07), grade II (12:45:00:07) and all other treatments and at par with application of RDF (NPKS Zn). Kamble and Kathmale (2015) reported highest available nitrogen and phosphorus in 125 per cent recommended dose of NPK through customized fertilizer in two equal splits.

**Table 2. Available major nutrients in soil after harvest of onion**

| | Treatments | Available nutrients (kg ha$^{-1}$) | | | Av. S |
|---|---|---|---|---|---|
| | | N | P | K | (mg kg$^{-1}$) |
| $T_1$ | Absolute Control | 140.3 | 14.28 | 302.8 | 7.34 |
| $T_2$ | RDF of NPK | 166.7 | 17.71 | 337.6 | 8.03 |
| $T_3$ | RDF of NPKS | 187.2 | 19.21 | 368.1 | 12.11 |
| $T_4$ | RDF of NPKS Zn | 192.1 | 21.62 | 387.1 | 13.06 |
| $T_5$ | RDF of NPK + FYM | 170.4 | 18.99 | 367.3 | 11.30 |
| $T_6$ | RDF of P through NPS-1( N and K through conventional fertilizers) | 182.2 | 19.73 | 366.3 | 11.75 |
| $T_7$ | RDF of P through NPS-2( N and K through conventional fertilizers) | 179.4 | 19.48 | 362.6 | 11.44 |
| $T_8$ | RDF of P through NPS Zn( N and K through conventional fertilizers) | 184.7 | 21.81 | 368.9 | 11.59 |
| $T_9$ | RDF of NPK + Sulphur equivalent to NPS 1 supplied in $T_6$ | 176.1 | 20.14 | 363.9 | 11.48 |
| $T_{10}$ | RDF of NPK + Sulphur equivalent to NPS 2 supplied in $T_7$ | 180.1 | 19.88 | 361.8 | 11.23 |
| $T_{11}$ | RDF of NPK + Sulphur and Zn equivalent to NPS Zn supplied in $T_8$ | 183.1 | 20.32 | 367.3 | 11.52 |
| | SE (m) ± | 5.0 | 0.25 | 4.81 | 0.50 |
| | CD at 5 % | 14.8 | 0.76 | 14.2 | 1.47 |

**Table 3. Available micronutrients in soil after harvest of onion**

| | Treatments | Available micronutrients (mg kg$^{-1}$) | | | |
|---|---|---|---|---|---|
| | | Zn | Fe | Cu | Mn |
| $T_1$ | Absolute Control | 0.52 | 9.34 | 3.45 | 11.07 |
| $T_2$ | RDF of NPK | 0.55 | 9.36 | 3.48 | 11.14 |
| $T_3$ | RDF of NPKS | 0.58 | 9.37 | 3.55 | 11.20 |
| $T_4$ | RDF of NPKS Zn | 0.67 | 9.42 | 3.59 | 11.27 |
| $T_5$ | RDF of NPK + FYM | 0.63 | 9.43 | 3.61 | 11.28 |
| $T_6$ | RDF of P through NPS-1( N and K through conventional fertilizers) | 0.55 | 9.37 | 3.52 | 11.21 |
| $T_7$ | RDF of P through NPS-2( N and K through conventional fertilizers) | 0.56 | 9.38 | 3.52 | 11.21 |
| $T_8$ | RDF of P through NPS Zn( N and K through conventional fertilizers) | 0.64 | 9.40 | 3.56 | 11.24 |
| $T_9$ | RDF of NPK + Sulphur equivalent to NPS 1 supplied in $T_6$ | 0.56 | 9.37 | 3.53 | 11.21 |
| $T_{10}$ | RDF of NPK + Sulphur equivalent to NPS 2 supplied in $T_7$ | 0.56 | 9.38 | 3.54 | 11.19 |
| $T_{11}$ | RDF of NPK + Sulphur and Zn equivalent to NPS Zn supplied in $T_8$ | 0.62 | 9.40 | 3.55 | 11.21 |
| | SE (m) ± | 0.017 | 0.03 | 0.05 | 0.04 |
| | CD at 5 % | 0.050 | NS | NS | NS |

The significantly highest available potassium (387.1 kg $ha^{-1}$) was recorded in treatment of recommended dose of NPK + FYM which was followed by treatment recommended dose grade III through NPS Zn compensation of N and K through conventional fertilizers. Waikar *etal.* (2015) was also reported similar findings. The significantly highest available S (13.06 mg $kg^{-1}$) was recorded with application of RDF along with S and Zn whereas, customized grades treatments, through grade I NPS (19:38:00:07) recorded highest S (11.75 mg $kg^{-1}$) as compared to the treatment of grade II (12:46:00:07) and grade III (12:45:00:05:01), but these treatments found on par with each other.This could be attributed to the supply of S and Zn which showed synergistic effect on S in soil solution.In brief, it is noticed that, the availability of N, P, K, and S increased with the balanced application of nutrients through conventional fertilizers or customized fertilizers.The findings are in line with the results reported by Ghotekar *et al.* (2015).

**Available micronutrients**

The micronutrients are required in very less quantity by plant which is influenced by available nutrients in soil after harvest of onion.The significantly highest available Zn content (0.67 mg $kg^{-1}$) was recorded in treatment application of RDF +S and Zn (Table 3). Higher available iron (9.43 mg $kg^{-1}$), available copper (3.61 mg $kg^{-1}$), available manganese (11.28 mg $kg^{-1}$) were recorded with application of RDF + FYM. The slight increase in Fe with combined application of inorganic fertilizers and FYM may be due to the fact that FYM increased the available Fe in soil.Organic matter may hasten soil reduction and cause more $CO_2$ production resulting faster and greater accumulation of available Fe in the soil. This may be attributed to increased stability of Cu complex implicating presence of greater amount DTPA -Cu bound with organic matter. Waikar *et al.* (2015) also reported application of 100 per cent RDF +Grade II noticed highest availability of micronutrients (Zn, Fe Cu and Mn) as compared to other treatments.

## CONCLUSION

It is inferred that, the application of balanced nutrition through conventional as well as customized fertilizers increased the onion bulb yield and improved available nutrients in soil after harvest of onion crop.

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# Assessment of Spatial Variability of Major and Micro Nutrients in Soils of Amravati District of Maharashtra

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## ABSTRACT

Delineation of major and micronutrients was carried out by randomly collected georeferenced surface (0-20) cm soil samples representing different soil units from 768 sites of 128 villages in Amaravati district of Maharashtra using Global Positioning System (GPS) to study the variability in availability of major and micro nutrients during 2011-12. The results revealed that pH, EC, $CaCO_3$ and OC of soils collected across different tehsils of Amravati district varied from 6.00 to 9.15, 0.101 to 0.510 dS $m^{-1}$, 1.62 to 12.12 per cent and 1.00 to 9.88 g $kg^{-1}$, respectively. Whereas, available NPK and S in soils ranged from 101.7 to 296.5 kg $ha^{-1}$, 2.21 to 46.80 kg $ha^{-1}$, 134.4 to 1019.2 kg $ha^{-1}$ and 8.83 to 47.93 mg $kg^{-1}$, respectively. The DTPA-Zn, Fe, Cu and Mn in soil of the study area ranged from 0.11 to 5.31 mg $kg^{-1}$, 2.49 to 49.62 mg $kg^{-1}$, 0.77 to 6.84 mg $kg^{-1}$ and 1.22 to 58.20 mg $kg^{-1}$, respectively. The low nutrient index was found in respect to available nitrogen (1.03), medium for available phosphorus (1.87), sulphur (2.02), zinc (1.68) and iron (1.71) and high for available potassium (2.76), copper (2.99) and manganese (2.68). The results obtained in the present study clearly showed a large variability in chemical properties of soil across the Amravati district. This information could aid in decision making for application of plant nutrients for higher monetary returns to the farmers and extension functionaries.

Green revolution has triggered to achieve higher production and nutritional security in the country. However, intensive cultivation of high yielding varieties, increased imbalanced use of fertilizers devoid of secondary and micronutrients, decreased use of organic manures and lack of crop residue recycling have let to depletion of native nutrient fertility and resulted in wide spread deficiencies of all nutrients. Application of fertilizers on the basis of soil characteristics associated with fertilizers recommendation may aid in minimizing the fertilizers input without any yield loss (Yadav *et al.,* 2018). Understanding of nutrient variability and distribution of soil properties is critical for farmers attempting to increase nutrients use efficiency and crop productivity. Information technology has provided tools *viz.,* Global Positioning System (GPS) which helps in collecting a systematic set of georeferenced soil samples and generating the spatial data about the distribution of nutrients through Geographical Information System (GIS). The information about spatial variability in chemical properties of soil had great importance in the selection of crops and cropping system and also extent the ideas about prevailing management practices (Weindorf and Zhu, 2010; Liu *et al*., 2013). Imbalanced and inadequate use of fertilizers coupled with low use efficiency of other inputs led to decline in the response efficiency of chemical fertilizer nutrients under intensive agriculture in recent years. The deficiency of major and micronutrients has become major constraint in sustainable crop productivity of soils and hence, there is need to know the spatial variability of nutrients of the soil (Katkar *et al.* 2018). Keeping this in view, the present investigation was undertaken to assess the status of major and micronutrients in soils and to identify and delineate areas of nutrient deficiencies in Amravati district of Maharashtra.

## MATERIAL AND METHODS

### Description of the study area

Amravati district of Maharashtra is situated between 20° 32' to 21° 46' North latitude and 76° 37' to 77° 27' East longitude. Total geographical area of the district is 12,21,700 ha and is divided into fourteen tehsils (Dharni, Chikhaldara, Anjangaon, Achalpur, Chandur bajaar, Morshi, Warud, Tiwasa, Amravati, Bhatkuli, Daryapur, Nandgaon (Khandeshwar), Chandur (Railway) and Dhamangaon. Average annual temperature of the district is maximum of 44.5$^0$C and minimum of 12.40$^0$C with mean annual rainfall of 842 mm.

### Soil sampling and analysis

GPS based seven hundred sixty eight surface

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soil samples (0-20 cm) were collected from 128 villages across all the fourteen tehsils of Amravati district. The sampling villages were selected using stratified random method. Six farmers from each village were selected based on land holdings. The soil samples were processed and analyzed for pH and EC in soil:water suspensions (1:2.5 w/v) as described by Jackson (1973). Organic carbon was determined by wet oxidation method described by Walkley and Black (Nelson and Sommers, 1982) and free $CaCO_3$ was determined by Rapid titration method (Piper, 1966). Available N was estimated by alkaline permanganate method (Subbiah and Asija, 1956), available P by Bray's method (Bray and Kurtz, 1945), available K by ammonium acetate extraction method (Jackson, 1967) and available S was estimated by turbidimetric method (Chesnin and Yien, 1951). Soil samples were extracted with 0.005M diethylene triamine penta acetic acid (DTPA) for estimation of available Zn, Fe, Cu and Mn using Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978). The nutrient indices were calculated by using the formula given by Parker *et al.* (1951) and categorized into low (<1.66), medium (1.66 – 2.33) and high (> 2.33).

The major and micronutrients were categorized as low, medium and high which is followed in Maharashtra state (Table 1).

## RESULTS AND DISCUSSION

### Soil properties

Data regarding various chemical properties of soils is depicted in Table 2. The pH of soils in study area was recorded slightly acidic to alkaline (6.00 – 9.15). The highest pH was observed in Amravati tehsil (9.15) and lowest in Chikhaldara tehsil (6.00). Maximum soil samples were found neutral to moderately alkaline in nature. All the soils were non-saline (0.101 to 0.510 dS $m^{-1}$) in nature and suitable for plant growth with a mean value of 0.17 dS $m^{-1}$ which was in normal range (< 1 dS $m^{-1}$). The organic carbon content in soils ranged from 1.00 to 9.88 g $kg^{-1}$. Calcium carbonate content in soils of the district varied from 1.62 to 12.12 per cent, which indicated, the soils are calcareous in nature. High calcium carbonate is harmful; it reduces the concentration of micronutrient cations in soils to such a level that the sensitive plant suffers from deficiency of micronutrients (Deb *et al.* 2012). The higher calcium carbonate content was noticed in Achalpur, Anjangaon, Bhatkuli and Dhamangaon tehsils. Organic carbon deficiency was recorded in 43.61 per cent soil samples across the district. The high temperature during summer and meager use of organic matter might have shown its deficiency in Amravati district. The soil samples collected from tehsils Warud, Chandur, Chandurbazar and Anjangaon showed organic carbon deficiency in 68.75, 63.90, 54.54 and 52.10 per cent samples respectively, indicating soils are heavily depletd in soil organic carbon.

**Table 1. Categorization of soil parameters and nutrients**

| S.N. | Parameters | Low | Medium | High |
|---|---|---|---|---|
| 1 | pH (1:2.5) | <6.5 (Acidic) | 6.5-7.5 (Neutral) | >7.5 (Alkaline) |
| 2 | EC (dS $m^{-1}$) | <1.0 | 1-2 | >2.0 |
| 3 | O.C. (g $kg^{-1}$) | <4.0 | 4-8 | >8.0 |
| 4 | $CaCO_3$ (%) | <3.0 | 3-8 | >8.0 |
| 5 | N (kg $ha^{-1}$) | <280 | 280-560 | >560 |
| 6 | P (kg $ha^{-1}$) | <14 | 14-28 | >28 |
| 7 | K (kg $ha^{-1}$) | <150 | 150-250 | >250 |
| 8 | S (mg $kg^{-1}$) | <10.0 | 10-20 | >20.0 |
| 9 | Zn (mg $kg^{-1}$) | <0.60 | 0.6-1.80 | >1.80 |
| 10 | Fe (mg $kg^{-1}$) | <4.50 | 4.50-18.0 | >18.0 |
| 11 | Cu (mg $kg^{-1}$) | <0.20 | 0.20-0.80 | >0.80 |
| 12 | Mn (mg $kg^{-1}$) | <2.0 | 2.0-8.0 | >8.0 |

(Source: Dr. PDKV, Akola)

### Macronutrients status

Data pertaining to macronutrients status of soils in all tehsils of the study area presented in Table 3. Available nitrogen was noticed in the range of 101.7 to 296.5 kg $ha^{-1}$, which showed widespread deficiency to the extent of 97 per cent. The deficiency of available nitrogen might be due to very less addition of organic manures and heavy uptake under intensive cultivation of improved high yielding varieties of different crops. Available P varied from very low to medium (2.21 – 46.80 kg $ha^{-1}$) indicating 34.38 per cent deficiency across the district. The deficiency of available P ascribed to its fixation in the form of calcium phosphate due to alkaline nature of soil. The available K ranged from 134 to 1019 kg $ha^{-1}$ and 3.12 per cent samples were found deficient while 17.05 per cent samples were found medium. The higher K status under these soils could be attributed to more intense weathering

**Table 2. Chemical properties of soils in Amravati district**

| S. N. | Tehsils | Total No. of samples | pH (1:2.5) | | EC (dS $m^{-1}$) | | $CaCO_3$ (%) | | Organic carbon(g $kg^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| **1** | Dharni | 72 | 6.10 – 7.30 | 6.68 | 0.101 – 0.241 | 0.16 | 1.62 – 9.37 | 6.79 | 1.09-9.88 | 5.84 |
| **2** | Chikaldara | 78 | 6.00 – 8.51 | 7.32 | 0.102 – 0.260 | 0.15 | 3.12 – 11.9 | 7.06 | 1.31-9.24 | 6.25 |
| **3** | Anjangaon | 48 | 8.01 – 8.90 | 8.55 | 0.138 – 0.225 | 0.17 | 5.87 – 11.75 | 9.78 | 1.06-8.90 | 4.52 |
| **4** | Achalpur | 66 | 8.10 – 8.91 | 8.45 | 0.124 – 0.510 | 0.17 | 7.50 – 12.12 | 10.16 | 1.00-8.79 | 4.68 |
| **5** | Chandurbazar | 66 | 7.10 – 8.40 | 7.93 | 0.101 – 0.414 | 0.15 | 4.87 -10.87 | 7.58 | 1.08-8.99 | 4.50 |
| **6** | Morshi | 48 | 7.11 – 8.06 | 7.65 | 0.102 – 0.184 | 0.14 | 5.12 – 10.25 | 7.72 | 1.05-9.11 | 4.31 |
| **7** | Warud | 48 | 6.97 – 8.05 | 7.61 | 0.108 - 0.181 | 0.14 | 3.12 -9.50 | 6.66 | 1.08-8.95 | 3.56 |
| **8** | Tiwasa | 36 | 7.15 – 7.92 | 7.72 | 0.111 – 0.189 | 0.15 | 5.25 – 9.75 | 7.45 | 1.06-8.99 | 4.69 |
| **9** | Amravati | 48 | 8.05 – 9.15 | 8.49 | 0.115 – 0.330 | 0.21 | 6.30 – 10.87 | 8.83 | 1.07-8.93 | 4.64 |
| **10** | Bhatkuli | 54 | 7.38 – 8.75 | 8.41 | 0.101 – 0.393 | 0.19 | 7.00 – 11.25 | 9.36 | 1.02-8.78 | 3.91 |
| **11** | Daryapur | 66 | 7.45 – 8.71 | 8.23 | 0.125 – 0.285 | 0.21 | 5.00 – 11.25 | 8.14 | 1.01-8.93 | 3.98 |
| **12** | Nandgaon Kh. | 60 | 7.35 – 8.25 | 7.90 | 0.110 – 0.218 | 0.17 | 3.0 – 10.25 | 7.72 | 1.10-8.96 | 4.36 |
| **13** | Chandur | 36 | 7.08 – 8.12 | 7.73 | 0.101 – 0.221 | 0.16 | 2.00 – 10.75 | 8.17 | 1.04-8.18 | 3.84 |
| **14** | Dhamangaon | 42 | 7.35 – 8.25 | 7.78 | 0.134 – 0.225 | 0.17 | 4.75 – 11.00 | 8.19 | 1.15-9.10 | 4.60 |
| **Amravati district** | | **768** | **6.00 – 9.15** | **7.86** | **0.101 – 0.510** | **0.17** | **1.62 – 12.12** | **8.08** | **1.00-9.88** | **4.65** |

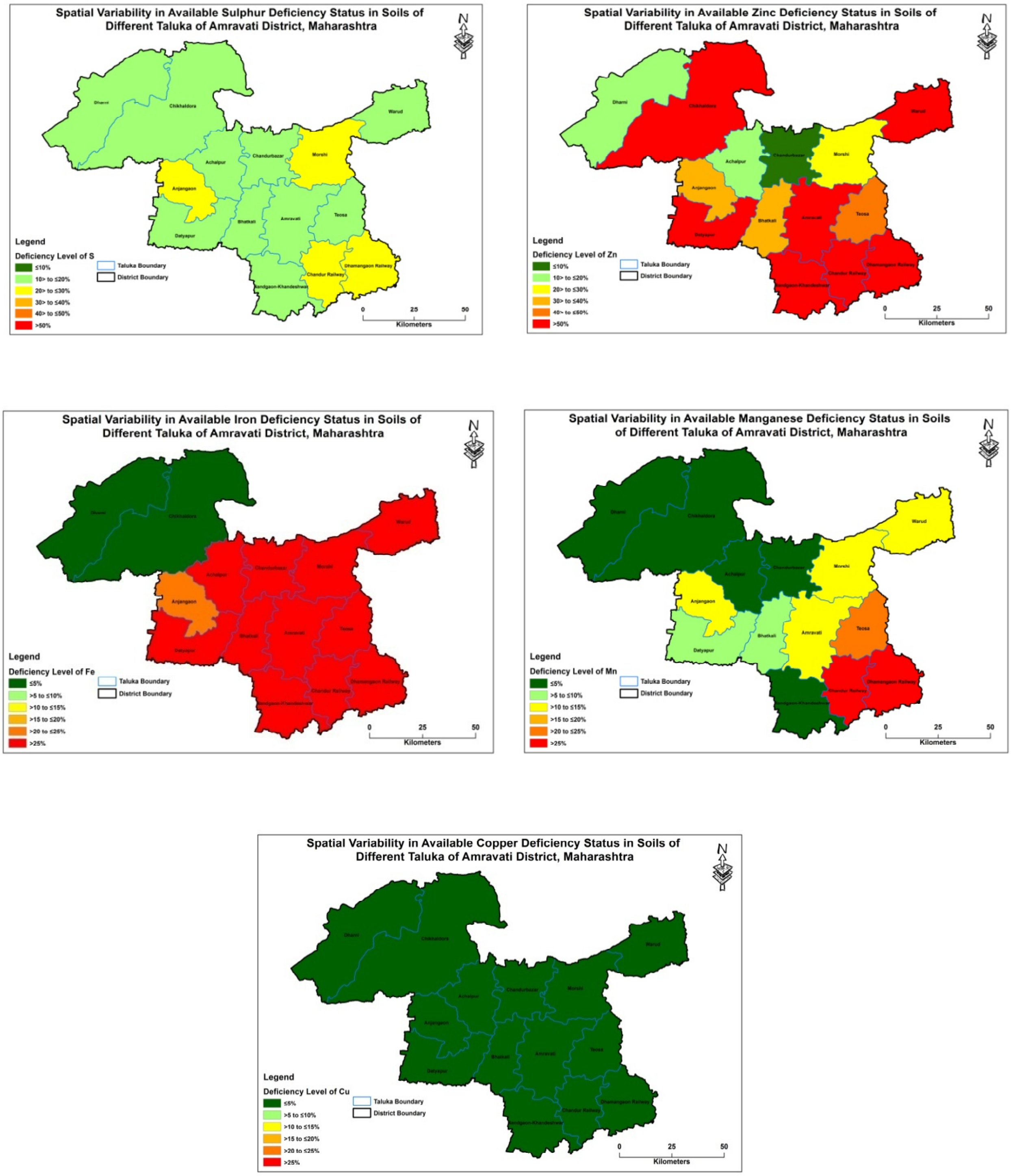


**Fig. 1. Spatial variability of secondary and micronutrients in soils of Amravati district of Maharashtra**

of K bearing minerals, release of labile K from organic residues, application of K fertilizers and upward translocation of K from lower depths along with capillary rise of ground water (Sharma and Anil Kumar, 2003). During post green revolution era, the available potassium was considered very high in many soils. The recent trends indicated that slight potassium deficiency occurred, showing response to its addition. The available sulphur varied from low to very high (8.83 to 47.93 g $kg^{-1}$) with 17.19 per cent deficiency, whereas 63.15 per cent samples were found medium (Fig. 1). The intensive cropping coupled with high analysis fertilizers devoid of sulphur might be depleting the sulphur status of soil. The application of balanced nutrition to the crops under intensive cultivation is essential for maintaining the soil fertility and sustainable productivity.

**Micronutrients status**

Data regarding micronutrients status of soils in Amaravati district of Maharashtra are presented in Table 4 and Fig. 1. DTPA-Zn of Amravati district as a whole, varied from 0.11 to 5.31 mg $kg^{-1}$ indicating 43.3 per cent deficiency, whereas 44.7 per cent samples of available Zn were noticed in medium category showing widespread deficiency of zinc. The highest deficiency of zinc was observed in Dhamangaon tehsil followed by Daryapur, Amravati and Chandur. The availability of micronutrient cations is generally low in alkaline soils and crops grown on these soils suffer from hidden hunger (Malewar, 2005). Major crops grown in these tehsils are cotton, soybean, pigeonpea, sorghum, pulses (blackgram, greengarm and chickpea), pearl millet, maize, safflower, sunflower and sesamum etc. The fruit crops like oranges and banana are also grown primarily in Warud tehsil. Intensive cultivation of these crops might have mined the zinc along with N, P and K over a long period. All the tehsils indicated wide spread zinc deficiency in the district. The deficiency of nutrients creates imbalance in soils which results into nutritional stress in plants. High pH and high contents of $CaCO_3$ can fix Zn in the soil and give rise to the reduction of available zinc (Hafeez *et al.,* 2013).

DTPA-Fe content showed wide variation (2.49 to 49.62 mg $kg^{-1}$) in the soils of Amravati district. Considering the soils having < 4.5 mg $kg^{-1}$ as low, 4.5 to 18.0 mg $kg^{-1}$ as medium and > 18.0 mg $kg^{-1}$ as high in iron status, the distribution of soil samples under these categories was 47.8, 33.2 and 19.0 per cent, respectively indicating that the soils are becoming deficient in iron like that of zinc. Shukla *et al.* (2016) reported low Fe content in forage and food grains produced in arid and semi-arid regions is attributed to acute Fe deficiency in soils (85% in Rajasthan, 23% in Gujrat, 22 % in Haryana and 21% in Maharashtra). Patil *et al.* (2004) reported 40.0 and 34.7 percent soils deficient in zinc and iron respectively in Vidarbha.

The DTPA extractable Cu in the soils of the study area ranged from 0.77 to 6.84 mg $kg^{-1}$. Patil and Sonar (1994) reported that, in swell-shrink soils of Maharashtra, available Cu was in the range of 0.58 to 1.7 mg $kg^{-1}$. The majority of soils in Amravati district were found sufficient in Cu content.

The DTPA-Mn status of soils ranged from 1.22 to 58.20 mg $kg^{-1}$. Gajbhe *et al.* (1976) reported that available Mn content in surface soils of Marathwada ranged from 13.3 to 65.20 mg $kg^{-1}$. Soils of Amravati district were sufficient in Mn and Cu.

**Nutrient indices**

The nutrient indices across the Amravati district (Table 5) ranged from 1.0-1.11, 1.52-2.09, 2.38-3.00 for available N, P and K, respectively, whereas it ranged from 1.82-2.38, 1.31 – 2.08, 1.04 – 2.81, 2.97 – 3.00 and 1.52 – 2.90 for available S, Zn, Fe, Mn and Cu, respectively. Notably low fertility rating was recorded for N in most of the tehsils, high for K, Cu and Mn, medium for P, S, Zn and Fe. In nutshell, overall fertility rating for nutrients in the soils of Amravati district revealed low N, high K, Cu and Mn and medium P, S, Zn and Fe status. The areas where the status of nutrients is medium may show deficiency in near future if the due care will not be taken for addition of organic manures and inorganic micronutrient fertilizers based on soil testing by the cultivators in the districts for intensive cultivation of different crops.

## CONCLUSION

The information technology based GPS-GIS technique has been found useful for systematic mapping of spatial variability of macro and micro nutrients. Among the macro nutrients, nitrogen with 97 per cent samples was found deficient, phosphorus with 34.38 per cent

**Table 3. Macronutrients status in soils of Amravati district**

| S. N. | Tehsils | Available nutrients (kg $ha^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | | P | | K | | S (mg $kg^{-1}$) | |
| | | Range | PSD | Range | PSD | Range | PSD | Range | PSD |
| 1 | Dharni | 158.0 - 294.8 | 91.66 | 2.25 – 41.78 | 54.14 | 145.6 – 638.4 | 4.16 | 9.26 – 27.18 | 19.44 |
| 2 | Chikaldara | 164.9 - 296.5 | 88.46 | 2.50 – 35.10 | 42.30 | 201.6 – 840.0 | 00 | 9.46 – 25.23 | 15.38 |
| 3 | Anjangaon | 105.4 - 295.0 | 89.60 | 6.24 – 37.06 | 18.75 | 148.0 – 873.6 | 2.08 | 8.85 – 47.93 | 16.67 |
| 4 | Achalpur | 101.7 -289.0 | 93.93 | 6.02 – 39.04 | 22.72 | 146.8 –1019.2 | 4.54 | 9.80 – 46.16 | 13.64 |
| 5 | Chandurbazar | 108.2 - 273.9 | 100 | 8.45 – 35.17 | 40.90 | 134.4 – 974.4 | 3.03 | 9.38 – 30.19 | 18.18 |
| 6 | Morshi | 115.9 - 210.7 | 100 | 6.29 – 33.26 | 27.08 | 190.4 –1019.2 | 00 | 9.64 – 24.04 | 18.75 |
| 7 | Warud | 110.2 - 221.3 | 100 | 2.21 – 34.57 | 35.41 | 134.4 – 806.4 | 4.16 | 9.74 – 28.81 | 12.50 |
| 8 | Tiwasa | 103.5 - 200.0 | 100 | 8.26 – 46.80 | 25.00 | 302.4 – 974.4 | 00 | 9.52 – 24.40 | 19.89 |
| 9 | Amravati | 104.9 - 242.3 | 100 | 8.33 – 41.18 | 20.83 | 146.8 – 918.4 | 4.16 | 9.32 – 29.77 | 18.75 |
| 10 | Bhatkuli | 126.4 -259.8 | 100 | 6.39 – 36.60 | 48.14 | 134.4 – 918.4 | 5.55 | 9.64 – 25.08 | 14.81 |
| 11 | Daryapur | 106.3 - 242.3 | 100 | 7.37 – 33.52 | 42.42 | 201.6 – 996.8 | 00 | 8.83 – 32.96 | 13.64 |
| 12 | Nandgaon Kh. | 115.9 - 238.9 | 100 | 8.64 – 41.54 | 25.00 | 208.9 – 851.2 | 00 | 9.09 – 28.08 | 20.00 |
| 13 | Chandur | 119.8 - 231.8 | 100 | 8.39 – 32.42 | 38.88 | 138.8 – 638.4 | 5.55 | 9.22 – 30.52 | 27.78 |
| 14 | Dhamangaon | 116.6 - 245.9 | 100 | 6.16 – 41.57 | 21.42 | 134.4 – 795.2 | 14.28 | 9.70 – 24.39 | 21.43 |
| | **Amravati district** | **101.7 - 296.5** | **96.9** | **2.21 – 46.80** | **34.38** | **134.4 – 1019.2** | **3.12** | **8.83 – 47.93** | **17.19** |

PSD – Per cent sample deficient

**Table 4. Micronutrients status in soils of Amravati district**

| S. N. | Tehsils | Available micronutrients (mg $kg^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Zn | | Fe | | Cu | | Mn | |
| | | Range | PSD | Range | PSD | Range | PSD | Range | PSD |
| **1** | Dharni | 0.35 – 5.31 | 15.3 | 4.53 – 48.06 | 0 | 2.30 – 6.63 | 0 | 5.20 – 58.20 | 0 |
| **2** | Chikaldara | 0.11 - 3.21 | 50.0 | 4.67 – 49.62 | 0 | 1.06 – 6.62 | 0 | 4.42 – 52.65 | 0 |
| **3** | Anjangaon | 0.26 – 3.67 | 45.8 | 3.45 – 39.93 | 25.0 | 0.86 – 6.36 | 0 | 1.80 – 39.34 | 0 |
| **4** | Achalpur | 0.34 – 4.93 | 24.2 | 2.49 – 35.0 | 28.8 | 1.38 – 6.52 | 0 | 4.26 – 48.0 0 | 0 |
| **5** | Chandurbazar | 0.26 – 4.42 | 19.70 | 3.90 – 20.58 | 30.3 | 1.33 – 6.84 | 0 | 1.82 – 39.88 | 0 |
| **6** | Morshi | 0.44 – 3.58 | 25.0 | 4.05 – 14.12 | 50.0 | 1.24 – 6.82 | 0 | 1.57 – 45.36 | 0 |
| **7** | Warud | 0.25 – 2.78 | 58.33 | 4.22 – 18.71 | 62.5 | 0.77 – 6.14 | 0 | 2.63 – 19.86 | 0 |
| **8** | Tiwasa | 0.22 – 3.85 | 44.4 | 3.26 -16.40 | 94.4 | 1.02 – 6.78 | 0 | 2.26 – 37.14 | 0 |
| **9** | Amravati | 0.16 – 3.99 | 64.6 | 3.13 – 11.7 | 95.8 | 1.40 – 6.82 | 0 | 1.47 - 19.93 | 0 |
| **10** | Bhatkuli | 0.27 – 4.34 | 37.0 | 3.24 – 16.82 | 33.3 | 0.88 – 5.35 | 0 | 1.22 – 19.95 | 1.8 |
| **11** | Daryapur | 0.17 – 1.60 | 65.15 | 3.53 – 15.87 | 74.2 | 1.24 – 5.21 | 0 | 1.79 – 49.67 | 1.5 |
| **12** | Nandgaon Kh. | 0.35 – 2.51 | 51.7 | 4.12 – 11.05 | 73.3 | 1.14 – 6.79 | 0 | 3.04 – 39.02 | 0 |
| **13** | Chandur | 0.23 – 1.00 | 261.1 | 3.49 – 13.9 | 92.7 | 1.03 – 6.63 | 0 | 2.12 – 17.98 | 0 |
| **14** | Dhamangaon | 0.19 – 1.38 | 69.1 | 4.16 – 7.12 | 90.5 | 1.25 – 6.00 | 0 | 2.17 – 16.54 | 0 |
| **Amravati district** | | **0.11 – 5.31** | **43.3** | **2.49 – 49.62)** | **47.8** | **0.77 – 6.84** | **0** | **1.22 – 58.20** | **0.3** |

PSD – Per cent sample deficient

**Table 5. Nutrient index values of soil available nutrients in different tehsils of Amravati district**

| S.N. | Name of the tehsils | No. of samples | Available nutrients | | | | Available micronutrients | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | N | P | K | S | Zn | Fe | Cu | Mn |
| 1 | Dharni | 72 | 1.08 | 1.52 | 2.62 | 1.82 | 2.01 | 2.67 | 3.00 | 2.90 |
| 2 | Chikaldara | 78 | 1.11 | 1.73 | 2.79 | 1.96 | 1.58 | 2.81 | 3.00 | 2.81 |
| 3 | Anjangaon | 48 | 1.10 | 2.08 | 2.91 | 2.21 | 1.60 | 1.96 | 3.00 | 2.54 |
| 4 | Achalpur | 66 | 1.06 | 2.09 | 2.75 | 2.38 | 1.93 | 1.84 | 3.00 | 2.83 |
| 5 | Chandurbazar | 66 | 1.0 | 1.83 | 2.84 | 2.08 | 2.08 | 1.80 | 3.00 | 2.77 |
| 6 | Morshi | 48 | 1.0 | 1.99 | 2.87 | 1.94 | 2.02 | 1.58 | 3.00 | 2.43 |
| 7 | Warud | 48 | 1.0 | 1.93 | 2.70 | 1.98 | 1.54 | 1.48 | 2.97 | 2.75 |
| 8 | Tiwasa | 36 | 1.0 | 1.91 | 3.00 | 2.17 | 1.75 | 1.06 | 3.00 | 2.31 |
| 9 | Amravati | 48 | 1.0 | 2.10 | 2.72 | 2.13 | 1.48 | 1.04 | 3.00 | 2.58 |
| 10 | Bhatkuli | 54 | 1.0 | 1.72 | 2.64 | 2.04 | 1.69 | 1.67 | 3.00 | 2.70 |
| 11 | Daryapur | 66 | 1.0 | 1.72 | 2.93 | 2.20 | 1.45 | 1.26 | 3.00 | 2.67 |
| 12 | Nandgaon Kh. | 60 | 1.0 | 2.05 | 2.78 | 1.88 | 1.50 | 1.27 | 3.00 | 2.80 |
| 13 | Chandur | 36 | 1.0 | 1.66 | 2.69 | 1.83 | 1.39 | 1.08 | 3.00 | 2.33 |
| 14 | Dhamangaon | 42 | 1.0 | 1.99 | 2.38 | 1.89 | 1.31 | 1.10 | 3.00 | 1.52 |
| | **Over all Mean** | **768** | **1.03** | **1.87** | **2.76** | **2.02** | **1.68** | **1.71** | **2.99** | **2.68** |

**Low - < 1.66, Medium - 1.66 - 2.33, High - > 2.33**

sample was found medium and potassium with 3.12 per cent sample was found sufficient, whereas sulphur with 17.19 per cent sample was found medium. The soils of Amravati district showed wide spread deficiency of zinc (43.3%) and iron (47.8%). The current status of spatial variability of micronutrients in soils of Amravati district will be helpful to suggest the efficient ways and methods of balanced nutrient application for enhancing the yields by using recommended quantities of organic manures and inorganic fertilizers in the areas of major and micro-nutrients deficiency.

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# Effect of Post-shooting Foliar Spray of Potassium on Yield and Quality Attributes of Banana

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## ABSTRACT

The present experiment entitled "Studies on post-shooting foliar application of potassium on yield and quality of banana" was conducted at Department of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola with an objective to study the effect of post shooting foliar applications of potassium on yield and quality of banana and find out suitable source and concentration of potassium to maximize yield and quality in banana. The results of experiment revealed that, the post shooting foliar spraying of sulphate of potash at 1.5 per cent resulted in obtaining higher quality yield with relatively higher benefit: cost ratio. The plant growth in terms of higher number of leaves per plant, maximum leaf chlorophyll with minimum days required to maturity were recorded in the plants which received foliar application of sulphate of potash @ 1.5 per cent. The yield attributing characters *viz.* maximum bunch weight, more number of hands per bunch and number of fingers per hand with maximum finger weight were found associated with post shooting foliar application of 1.5 per cent Sulphate of potash. Similarly maximum fruit yield $ha^{-1}$ was also recorded in the same treatment with a minimum physiological losses and maximum shelf life. The superior fruit quality in respect of fruit size, total soluble solids, titratable acidity, total sugars and sugar: acid ratio was also recorded in 1.5 per cent SOP through foliar applications. The same treatment was also found superior in respect of benefit: cost ratio.

Banana (*Musa* spp.) is one of the oldest tropical fruits cultivated by man from the pre-historic time in India with great socio-economic significance. It is grown in all tropical regions and plays a key role in the economics of many developing countries. Banana and plantains are grown in about 120 countries. Banana is cultivated in the world in area of 4.80 million ha with global production of 99.99 million tones having productivity of 20.80 Mt $ha^{-1}$. India contributes 33.40 per cent in total world production of banana and ranked first in area and production in the world. In India, Maharashtra is leading state in banana production where banana is grown on 83,000 ha having a total production of 4.83 million tons with the productivity of 58.20 tons $ha^{-1}$ (Anon., 2017).

Banana being a gross feeder requires high amount of nutrients for proper growth and production. However, it draws the nutrients from a very limited soil depth because of its shallow root system. The choice and dosage of nutrients to be applied depends on the cultivar, initial soil fertility, stage of plant growth, climate etc. Now-a-days, the practices of application of chemicals on banana bunch for improving the growth, maturity, yield and quality of fruits is gaining popularity.

A judicious use of fertilizers not only gives high yield but also improves the quality of the fruit. Banana is a potassium loving crop and high potassium availability is important at fruiting stage. Any limitation in the supply of nutrients at the shooting stage affects bunch size and quality in banana. Among the several factors affecting fruit quality, adequate potassium application is considered to be of utmost importance in banana cultivation. Potassium is known to influence fruit yield in general and fruit quality in particular (Tandon and Sekhon, 1988). It helps in photosynthesis thus, reflecting in fruit size and yield. The higher chlorophyll content in leaves and developing fruits reflects the efficiency of photosynthesis.

Even though K is abundant in many banana growing soils, the bulk of soil K is unavailable to plants due to both plant and environmental factors, therefore additional application through bunch feeding has been found beneficial. In high value crop like banana quality standards have become the most important factor influencing yield and farmer's income.

## MATERIAL AND METHODS

The present investigation entitled "Studies on

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post-shooting foliar application of potassium on yield and quality of banana" was conducted during 2013-14 at Main garden Department of Horticulture and analytical work was carried out at analytical laboratory of Department of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

The experiment was laid out in Randomized Block Design with nine treatments with two different sources of potash fertilizers *viz*., SOP and $KH_2PO_4$ @ 0.5, 1.0, 1.5 and 2.0 per cent respectively along with control treatment which were replicated three times. The treatments were imposed to the crop during two different stages of crop growth. The first spray was given immediately after opening of the last hand and second, exactly one month after first spray.

The observations on the total number of leaves retained at harvest, the total chlorophyll content (Yoshida *et al.,* 1971), number of days taken from shooting to harvest (maturity days), weight of the bunch, total number of hands and fingers in a bunch, average weight of the finger, pulp weight, peel weight and their ratio (Gottreich *et al.,* 1964), TSS, the total sugars (Somogyi, 1952), titrable acidity (A.O.A.C., 1960), sugar/acid ratio and physiological loss in weight and shelf life were made.

## RESULTS AND DISCUSSION

### Growth parameters

Foliar spray of potassium significantly increased the number of leaves at harvest and recorded highest (15.0) with the application of 1.5 per cent SOP treatment. Baruah and Mohan, (1991) indicated that reduced longevity of banana leaves can be due to high mobility of K from old leaves to other plant parts and as a result, leaf duration can be severely hampered by low K content.

In the present investigation, the relative decrease in leaf number at harvest was low in plants receiving foliar spray. The data regarding leaves per plant is depicted in Fig.1. The synthesis and transport of plant assimilates to the developing banana fruit is greatly affected by the retention of green leaves after the flowering stage, especially when assimilate flow from other plant parts becomes limiting. Senescing leaves also contribute their own stored assimilates to developing fruit.

Banana plants receiving foliar spray of potassium had significantly higher leaf chlorophyll content (2.03 mg $leaf^{-1}$) at harvest. The data regarding leaf chlorophyll content is depicted in Fig.1. Retention of chlorophyll pigment during the post-shooting growth stage helps fruit bunches accumulate photosynthates, thus contributing to fruit bunch size, days to maturity and yield (Kannan, 1980).

Post shooting spray of SOP significantly reduced the maturity days. When compared to other treatments, SOP spray took lesser number of days (58.67) for fruit maturity and it was the shortest at 1.5 per cent SOP. In post shooting nutrient spray investigation, the reduction in bunch development phase was noticed due to faster growth rate of fingers that was evident from higher leaf chlorophyll contents owing to additional nutrient supply and faster rate of translocation of assimilates from source to sink, aided by additional K (Evans, 1971).

### Physicochemical parameters

All plant bunches treated with different potassium sources and their concentrations were significantly different. An application of 1.5 per cent SOP produced the heaviest fingers (160.17 g) which was at par with 2.0 per cent SOP (149.63 g) and 2.0 per cent $KH_2PO_4$ (147.97 g). On the contrary, control plant bunches produced the lightest fingers (113.93 g). The data regarding finger weight is depicted in Fig. 2. Increase in finger weight by foliar applications of potassium might be due to the increase in production of promoting endogenous and enhancement of nutrient uptake in addition to the role of potassium on productivity of banana plants (Nijjar, 2000).

The bunch sprayed with the potassium substances had significant effects on pulp weight per finger. The maximum pulp weight (134.80 g) was recorded when the bunch sprayed with 1.5 per cent sulphate of potash. While, the minimum pulp weight (92.70 g) was recorded in control ($T_9$).

The bunch sprayed with the potassium substances had significant effects on peel weight. The maximum peel weight (25.37 g) was recorded in where the bunch sprayed with 1.5 per cent sulphate of potash, while, the minimum peel weight (21.23 g) was recorded in control ($T_9$).

Increase in pulp and peel weight might be due to efficient partitioning of carbohydrates and mobilization in developing bunches resulting in good pulp and peel recovery. The accelerated rate of cell division and enlargement favoured by auxin biosynthesis prompted by nitrogen and potassium recorded higher pulp and peel weight per finger (Mulagund *et al.,* 2015). And also influence of potassium on filling of banana fingers has been registered by earlier workers like Mustaffa *et al.,* (2004) in Cv. Nendran.

Perceptible differences were realized for pulp: peel ratio among the different concentration of SOP and $KH_2PO_4$. However, spraying of 1.5 and 2.0 per cent of SOP relatively registered higher ratios (5.32 and 5.19 respectively).

The increase in pulp weight, peel weight and pulp to peel ratio of banana might be due to post shooting foliar applications of potassium in which potassium plays an important role in the translocation of newly synthesized photosynthates and had a beneficial effect on the mobilization of stored material (Mengal and Kirkby, 1987). Potassium also involved in the activation of more than 60 enzymes, which are necessary for essential plant processes such as energy utilization, starch synthesis, N metabolism and respiration (Wallingford, 1980).

**Quality parameters**

The data presented in table 1 showed the quality character viz., TSS, Total sugar Titratable acidity, Sugar: Acid ratio, shelf life and organoleptic test in banana which were affected due to various foliar applications of fertilizers. All these parameters had significant difference through various treatments. The maximum TSS percentage was noted in foliar spray of SOP @ 1.5 per cent. This might be due to post shooting application of K favours the conservation of starch into simple sugars during ripening by activating sucrose synthase enzyme, resulting higher sugar content in fruits. Similar results were also noted by Kumar and Kumar (2008) and Kumar (2010) in banana.

In banana, fruit quality is mainly judged by the sugar content and acidity in the pulp. The maximum total sugar was noted in SOP 1.5 per cent and this might be due to potassium is involved in carbohydrate synthesis, breakdown and translocation and synthesis of protein and neutralization of physiologically important organic acids (Tisdale and Nelson, 1966).

The PLW from harvested fruits, especially under tropical conditions, causes severe economic losses. Several workers have tried nutrient treatments at post-shoot stage to reduce PLW (Swietlik and Faust, 1984). Grand naine variety receiving foliar spray at 1.5 per cent SOP had similar significant reductions in PLW.

The days to edible ripening were fewer in foliar spray treatments - an observation which could be related to the reduced PLW experienced in these treatments. Both the green-life and shelf-life of fruit were significantly lengthened by a maximum of 5.3 and 8.7 days past the control, respectively.

Foliar SOP sprays improved final fruit yield and net income (Table 1). The 1.5 per cent SOP treatment was most profitable and doubled net income compared to the control. Yield, quality, and economic traits all suggest significant advantages from foliar spray application during the post-shoot growth stage.

**Yield and yield attributing characters**

Improvements in fruit bunch weight and yield are the culmination of all desirable traits that perform well under optimum conditions including balanced nutrition. Foliar spray concentration of potassium had a significant and positive impact on bunch weight. Fruit bunch components including: hand and finger number, finger length, girth, and weight, were positively impacted by treatment with foliar spray (Table 1).

Post shooting foliar spray concentration of potassium had a significant and positive impact on bunch weight. The significantly highest bunch weight (29.67kg) was observed with the application of 1.5 per cent SOP which at par with 2.0 per cent $KH_2PO_4$ (25.67 kg), while minimum bunch weight (19.00 kg) registered under control treatment.

The favourable influence of SOP as compared to $KH_2PO_4$ on the production of heavier bunches might be attributed to the heavier dry matter and starch accumulation and additionally promoted by the sulphur

**Table 1. Influence of post shooting foliar applications of potassium on quality and yield contributing parameters of banana**

| Treatment | No.Fruit quality parameters | | | | | | Yield and yield attributing character | | | | Economics |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | TSS(°B) | Total Sugar (%) | Titratable acidity (%) | Sugar: acidratio | PLW (p%) | Shelf life (Days) | Bunch weight (Kg) | Hands bunch$^{-1}$ | Fingers bunch$^{-1}$ | Fruit yield ha$^{-1}$ (tones) | B:C ratio |
| $T_1$ (0.5 per cent SOP) | 20.50 | 15.04 | 0.53 | 28.48 | 13.0 | 8.33 | 23.33 | 9.00 | 146.33 | 103.69 | 1.42 |
| $T_2$ (1.0 per cent SOP) | 21.80 | 15.78 | 0.34 | 53.74 | 8.3 | 8.67 | 22.67 | 9.00 | 147.67 | 100.73 | 1.37 |
| $T_3$ (1.5 per cent SOP) | 22.97 | 18.15 | 0.30 | 63.03 | 6.2 | 10.67 | 29.67 | 9.67 | 157.67 | 131.84 | 1.77 |
| $T_4$ (2.0 per cent SOP) | 21.37 | 16.29 | 0.38 | 45.21 | 11.2 | 8.00 | 22.67 | 9.00 | 151.00 | 100.73 | 1.34 |
| $T_5$ (0.5 per cent $KH_2PO_4$) | 20.47 | 14.80 | 0.55 | 27.55 | 10.0 | 9.00 | 22.67 | 9.33 | 144.00 | 100.73 | 1.33 |
| $T_6$ (1.0 per cent $KH_2PO_4$) | 20.67 | 15.01 | 0.58 | 26.07 | 10.0 | 8.67 | 22.33 | 9.00 | 146.67 | 99.25 | 1.25 |
| $T_7$ (1.5 per cent $KH_2PO_4$) | 21.23 | 17.40 | 0.32 | 56.03 | 12.5 | 8.67 | 24.33 | 9.00 | 146.00 | 108.14 | 1.31 |
| $T_8$ (2.0 per cent $KH_2PO_4$) | 22.47 | 15.39 | 0.36 | 45.81 | 11.8 | 9.00 | 25.67 | 9.00 | 151.00 | 114.06 | 1.32 |
| $T_9$ (Control) | 19.70 | 13.35 | 0.85 | 16.94 | 12.4 | 7.67 | 19.0 | 8.33 | 128.33 | 84.44 | 1.18 |
| SE (m) ± | 0.52 | 0.05 | 0.08 | — | 0.20 | 0.29 | 1.39 | 0.19 | 2.58 | 6.17 | — |
| CD at 5per cent | 1.57 | 0.15 | 0.24 | — | | 0.86 | 4.18 | 0.57 | 7.76 | 18.58 | — |

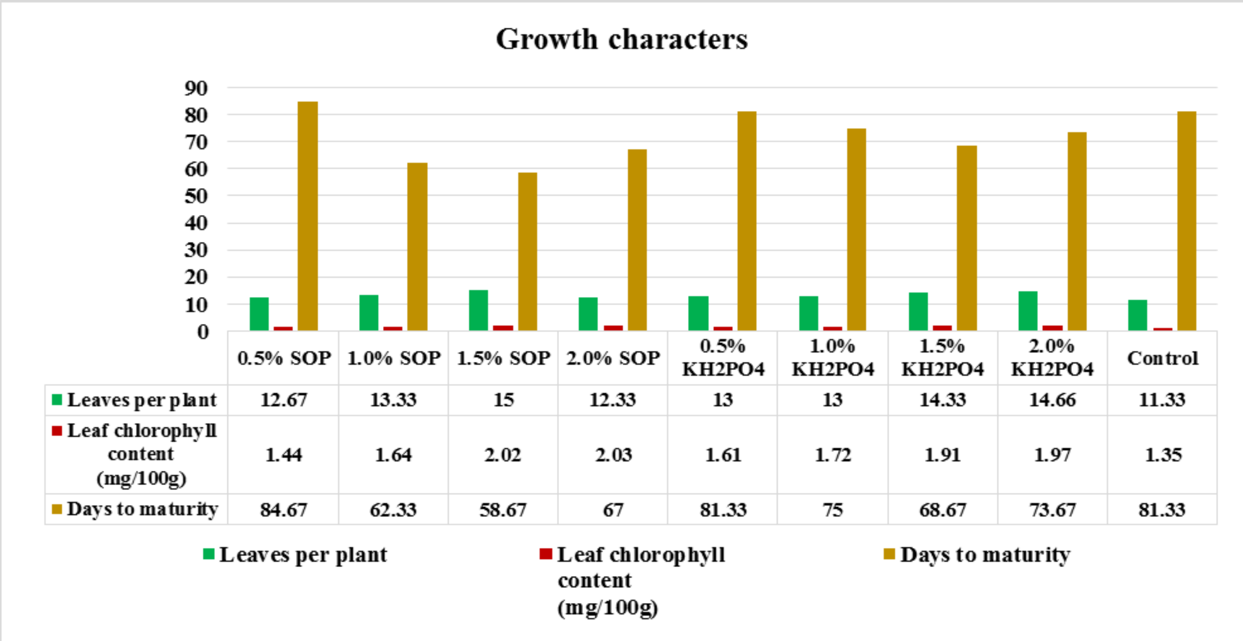


**Fig. 1.** **Influence of post shooting foliar applications of potassium on leaves per plant, leaf chlorophyll content and days to maturity of banana**

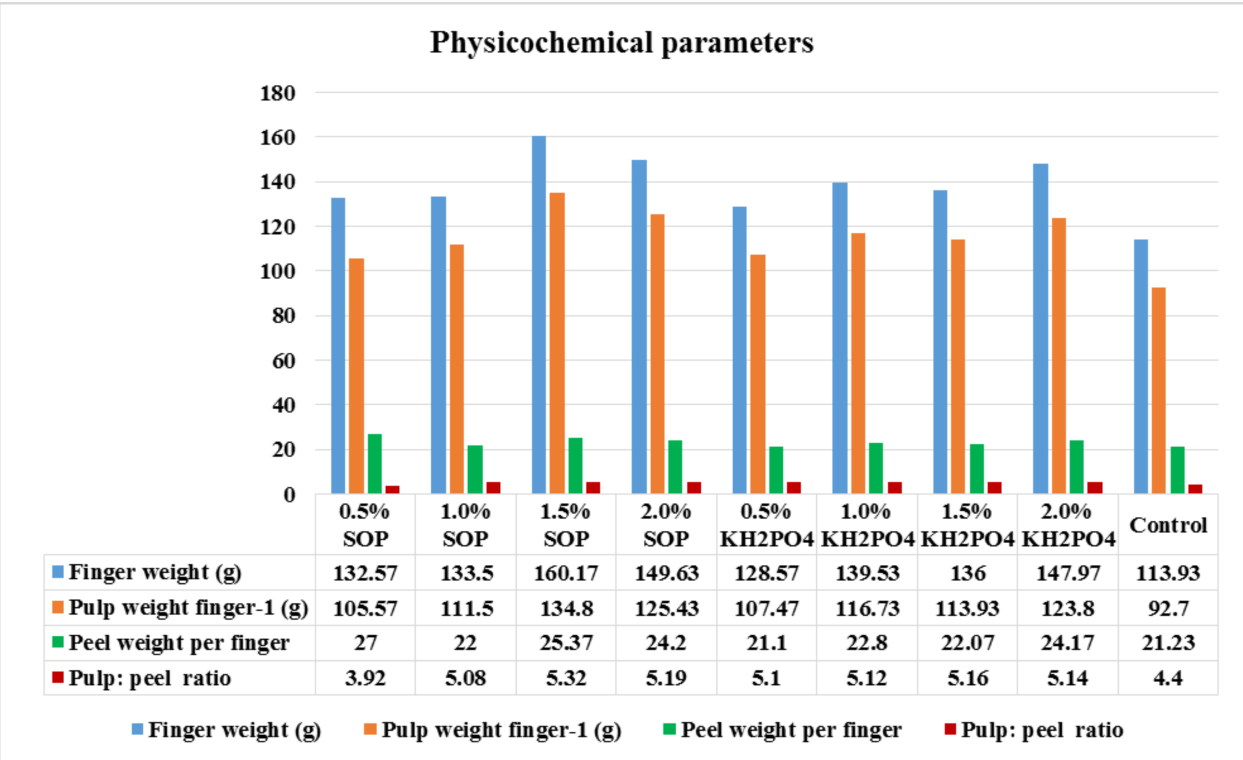


**Fig. 2.** **Influence of post shooting foliar applications of potassium on finger weight, pulp weight per finger peel weight per finger and pulp: peel ratio of banana**

presented in SOP. The influence of sulfur in enhancing fruit yield in bananas was stressed by Kumar and Kumar (2008).

The SOP concentrations exerted significant influence on number of hands per bunch. The spray of sulphate of potash at 1.5 per cent ($T_3$) resulted in production at higher number of hands (9.67 hands bunch$^{-1}$). Increase in number of hands it might be due to K application which might be attributed to the improvement in vegetative growth of plant as well as efficient transfer of photosynthates to the economic part of the plant (Dutta *et al.* 2011). Potassium not only promotes the translocation of newly synthesized photosynthates but also has a beneficial effect on the mobilization of stored material (Mengal and Kirkby, 1987).

Number of fingers per bunch was registered maximum with 1.5 per cent SOP (157.67 fingers bunch$^{-1}$) which was at par with treatment 2.0 per cent SOP and $KH_2PO_4$ (151.0 fingers bunch$^{-1}$) each while minimum number of fingers per bunch was recorded in control (128.33 fingers bunch$^{-1}$). The increase in the number of fingers per bunch might be due to K application which attributed to the improvement in vegetative growth of plant as well as efficient transfer of photosynthates to the economic part of the plant (Marshner, 1995) and (Dutta *et al.,* 2011).

The fruit yield per hectare was recorded maximum with foliar applications of sulphate of potash at 1.5 per cent (131.84 tonnes ha$^{-1}$) which was at par with 2.0 per cent $KH_2PO_4$ (114.06 tonnes ha$^{-1}$), while minimum fruit yield recorded by control treatment (84.44 tonnes ha$^{-1}$). Higher in fruit yield might be due to the post shooting foliar application of potassium because potassium application causes accumulation of more food material in the plants and lead to an efficient utilization of the same for development of fruit. It increases the efficiency of metabolic processes of the plant and thus encouraged the growth of plant and fruit (Singh *et al*, 1986).

The highest benefit cost ratio (1.77) was recorded with the application of SOP 1.5 per cent spray, whereas the least by control treatment. $KH_2PO_4$ treatment noted lower benefit cost ratio as compared to SOP treatments which was due to higher cost of $KH_2PO_4$ which denoted the usefulness of post shooting nutrient spray in terms of economics. These results are in close agreement with Kumar and Kumar (2008) who recorded higher benefit cost ratio for SOP spray.

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# Effect of Different Media and Time of Cutting on Rooting and Growth of Pomegranate Cuttings

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## ABSTRACT

An experiment was carried out during the year 2017-18 at Main Garden, Department of Horticulture, Akola with objectives to find out suitable media and time of cutting for better rooting and growth of pomegranate cuttings.The experiment was laid out in Factorial Randomized Block Design The treatment consisted of nine different rooting media ($M_1$ - soil, $M_2$ - silt, $M_3$ - soil + cocopeat, $M_4$ - soil + vermicompost, $M_5$ - silt + cocopeat, $M_6$ - silt + vermicompost, $M_7$ -soil + silt, $M_8$ -soil + silt + vermicompost, $M_9$ -soil + silt + cocopeat ) and three different time of cutting ($T_1$ -15$^{th}$January, $T_2$ - 30$^{th}$January and $T_3$ -15$^{th}$ February) with 27 combination and replicated three times. The result of present investigation indicated that, the response of different media varied with respect to different time of cutting.The treatment combination $M_8T_1$ (soil + silt + vermicompost and cutting taken on 15$^{th}$ January) took the minimum period required for rooting (23.09 days), maximum final survival of rooted cutting (86.66%), fresh weight of root (2.88 g) and dry weight of root (0.90 g). The maximum number of roots per cutting (29.27) observed intreatment combination $M_9T_1$ (soil + silt + cocopeat media and cutting taken on 15$^{th}$ January). In the analytical observations viz., maximum nitrogen uptake by cutting (1.94%) and maximum potassium uptake by cutting (2.12%) obtained when cutting planted in soil + silt + vermicompost media and Maximum phosphorus uptake by cutting (8.93 %) in silt + vermicompost media. Similarly, maximum nitrogen, potassium and phosphorus uptake by cutting (1.42%, 4.02% and 7.72%), respectively obtained when cutting taken on 15$^{th}$January.

Pomegranate (*Punica granatum* L.) belongs to family Punicaceae is one of the preferred table fruits in tropical and sub-tropical regions of the world. The wide adaptability, hardy nature, low input needs, high yields, better keeping quality and therapeutic values of fruits establish its value as a remunerative fruit crop in India and elsewhere. India is one of the largest producers of pomegranate in the world. A native to Iran (Persia), it is found from Kanyakumari to Kashmir, but it is cultivated commercially only in Maharashtra. Large-scale plantations are also seen in Gujarat, Rajasthan, Karnataka, Tamil Nadu, Andhra Pradesh, Uttar Pradesh, Punjab and Haryana. In India, it is considered as a crop of arid and semi-arid regions because it withstands different soil and climatic stresses. It occupies a cultivated area of 180.64 thousand hectares with 1789.31 thousand MT of production (Anon., 2017). Recently, Pomegranate is described as nature's power fruit, is a plant used in folklore medicine for the treatment of various diseases (Moneim and Abdel, 2012; Ajaikumar *et al.* 2005) widely growing in the Mediterranean region. *Punica granatum* L. can be propagated by seed, sucker, cuttings, grafting and layering. Rooting of pomegranate can be enhanced by the use of various suitable growing media, which directly affects the development and later maintenance of the extensive functional rooting system.

Use of suitable growing media or substrates is essential for the production of quality horticultural crops. Some of the soilless media used are vermiculite, perlite, cocopeat, peat, sand, soil, silt etc. A good growing medium would provide sufficient encourage or support to the plant, serves as reservoir for nutrients and water, allow oxygen diffusion to the roots and permit gaseous exchange between the roots and atmosphere outside the root substrate (Hartman *et al,* 2000). It is, therefore, necessary to find out the standard rooting media for better survival and maximum rooting of cuttings in any horticultural crop. The present study aims, to find out the effect of different media and time of cutting on root-initiation of pomegranate cuttings.

## MATERIAL AND METHODS

The research studies were carried out at Main Garden, Department of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the year 2017-18. For planting cuttings of *Punica granatum* L., nine

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rooting media were selected viz., $M_1$ - soil, $M_2$ - silt, $M_3$- soil + cocopeat, $M_4$ - soil + vermicompost, $M_5$ - silt + cocopeat, $M_6$ - silt + vermicompost, $M_7$ - soil + silt, $M_8$ - soil + silt + vermicompost and $M_9$ - soil + silt + cocopeat with three different time of cutting $T_1$ -15th January, $T_2$- 30thJanuary and $T_3$ -15th February) with 27 combination and replicated three times.

The plants of cultivar Bhagwa selected for preparing cutting were vigorous, healthy and free from insects, pests and diseases. Cuttings of pencil size having 12-15 cm length with the help of sharp secateurs. The basal portion was made just below the node without any injury to the bud and the proximal end, a slanting cut was made about 1.3 cm above the node. At the time of planting, 7.5 cm basal portion of cuttings was inserted in the rooting media followed by light watering. Statistical analysis was performed under Factorial Randomized Block Design (Snedecer and Cochran, 1968).

## RESULTS AND DISCUSSION

**Effect of different rooting media and time on period required for rooting**

The data presented in Table 1, showed the significant effect due to different media. The minimum period required for rooting in cutting was observed in media ($M_8$) soil + silt + vermicompost (23.36 days).While, the maximum period required (31.97 days) in the cutting which were planted in media ($M_6$) soil + silt + vermicompost.

The effect of time of cutting on period required for rooting was found to be significant (Table 1). The cutting taken on ($T_1$) 15th January took shortest duration for rooting in cutting (25.93 days), Whereas, the longest duration for rooting in cutting were taken in cutting taken ($T_3$) on 15th February (27.58 days).

The interaction effect of different media and time of cutting on period required for rooting in cutting was significantly influenced by the different combinations. The minimum days (23.09 days) required for rooting in cutting was observed in treatment combination ($M_8T_1$) soil + silt + vermicompost media and cutting taken on 15th January. While the maximum period (33.53 days) required for rooting in cutting found in treatment combination ($M_6T_2$) silt + vermicompost media and cutting taken on 30th January.

The above results might be due to the fact that congenial weather conditions like optimum temperature and high relative humidity helped in early rooting. The similar findings have also been reported by Shah *et al.* (2006) in *Ficus sp.* and Shadparvar *et al,* (2011) in Hibiscus.

**Effect of different media and time on final survival of rooted cutting**

The significant effect due to different media on final survival of rooted cutting were also found to be significant. The maximum final survival of rooted cutting (75.55 per cent) was observed in media ($M_8$) soil + silt + vermicompost. While, the minimum final survival of rooted cutting (40.00 per cent) was observed in ($M_2$) silt media.

Similarly, the time of cutting influence the final survival of rooted cutting significantly. Amongst the different time of cutting, maximum final survival of rooted cutting (56.29 %) were observed in ($T_1$) cutting taken on 15th January. While the minimum final survival percentage of rooted cutting (45.51 %) was found in ($T_2$) cutting taken on 15th February.

The interaction effect of different media and time of cutting on final survival of rooted cutting were also found to be significant. The maximum final survival of rooted cutting (86.66 %) was noted in treatment combination ($M_8T_1$) soil + silt + vermicompost media and cutting taken on 15thJanuary, while the minimum final survival of rooted cutting (33.33 %) was found in treatment combination ($M_2T_3$) silt media and cutting taken on 15th February.

It might be attributed due to the fact that, cutting taken during spring (January) had the favourable temperature, humidity and other weather parameters which might be help in better sap flowing condition that ultimately reflect in better final survival percentage.Similar findings have been reported by Sharma (1993) in mulberry, Singh and Nair (2003) in ornamental plants and Irshad *et al.* (2014) in kiwi fruit.

**Effect of different rooting media and time of cutting on percentage of rooted cutting**

The significant effect of different media on percentage of rooted cutting was found at 90 days after planting of cutting. The maximum percentage of rooted cutting was observed in ($M_8$) soil + silt + vermicompost media which was significantly superior over all treatments. Whereas minimum percentage of rooted cutting (52.22 %) was noted in ($M_1$) soil media (Table 1).

The different time of cutting influences the percentage of rooted cutting significantly. The maximum percentage of rooted cutting (68.52 %) was observed in ($T_1$) cutting taken on 15th January. Whi%per cent) was observed in ($T_3$) cutting taken on 15th February.

The presence of rooting inhibitor is minimum and rooting stimulator is maximum in the month of January. These factor causes that higher percentage of rooted cutting was observed in the month of January as compared to October. The findings are in agreement with earlier researchers like Waheb *et al.* (2011) in citrus rootstock cuttings and Omer (2003) in kiwifruit.

An interaction effect of different rooting media and time of cutting on percentage of rooted cutting was found to be non-significant at 90 days after planting of cutting.

**Effect of different media and time of cutting on number of roots per cutting**

Significantly maximum numbers of roots (28.32) were noted in ($M_8$) cuttings planted in the media soil + silt + vermicompost. However the minimum number of roots (13.40) recorded in the ($M_2$) silt media (Table 1).

This results might be due to vermicompost which has maximum pore space, aeration and water holding capacity and has ability to supply nutrients in available form such as nitrate, nitrogen and soluble phosphorus which are necessary for root growth.Results obtained are in accordance with the results of Ferguson and Young (1985) in passion fruit and Omer (2003) in kiwi fruit.

The significant effect due to different time of cutting on number of roots. was noticed and the maximum number of roots (22.06) was observed in ($T_1$) cutting taken on 15 January was found to be significantly superior over all treatments. However the minimum number of roots (21.28) were recorded in ($T_3$) cutting taken on 15 February. The findings are in agreement with earlier researchers like Waheb *et al.* (2011) in guava and Ansari (2013) in pomegranate.

Significantly maximum number of roots (29.27) was observed in treatment combination ($M_9T_1$) soil + silt + cocopeat media and cutting taken on 15January. However the minimum number of roots (13.28) was obtained from ($M_2T_1$) silt media and cutting takenon 15 January.

Cocopeat encourages the induction of adventitious roots, perhaps its richness in cytokinin, a harmone which alongside Auxins, favours cell division, being responsible for adventitious root development (Davis *et al,* 1991).The above results are in similar line of earlier findings reported by Nagwa (2007) in *ficus spp.* and Bosila *et al.* (2010) in bougainvillea.

**Effect of different rooting media and time of cutting on length of root**

The significant effect due to different media on length of root was found to be significant. The longest length of root (17.17 cm) was obtained from the cutting planted in ($M_8$) soil + silt+ vermicompost media. While minimum length of root (6.62 cm) was found in ($M_5$) silt + cocopeat (Table 2).

It might be attributed due to the fact that, vermicompost is the rich source of mineral nutrition and its addition to media increases quality of media by increasing microbial activity and microbial biomass which are key components in nutrient cycling and production of plant growth regulators. The above results are in similar line of earlier findings reported by Shadparwar *et al.* (2011) in hibiscus and Manila *et al.* (2017) in pomegranate.

Nonsignificant variation effect due to different time of cutting on length of root was noticed.

An interaction effect of different rooting media and time of cutting on length of root were also found significant. Treatment combination ($M_8T_1$) soil + silt + vermicompost media and cutting taken on 15 January showed noted longest root (18.0) per cutting. However minimum length (6.24 cm) was found in treatment combination ($M_5T_3$) silt + cocopeat media on and cutting planted taken on 15 February.

This might be due to act that, the combined effect of vermicompost and more bright sunshine in summer

**Table 1. Effect of different media and time of cutting on rooting characteristics**

| Treatment | Period required for rooting (days) | | | | Final survival of rooted cutting | | | | Percentage of rooted cutting | | | | Number of roots per cutting | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Time of cutting | | | | Time of cutting | | | | Time of cutting | | | | Time of cutting | | | |
| Media | $T_1$ (15th January) | $T_2$ (30th January) | $T_3$ (15th February) | Mean | $T_1$ (15th January) | $T_2$ (30th January) | $T_3$ (15th February) | Mean | $T_1$ (15th January) | $T_2$ (30th January) | $T_3$ (15th February) | Mean | $T_1$ (15th January) | $T_2$ (30th January) | $T_3$ (15th February) | Mean |
| $M_1$ (soil) | 24.46 | 23.28 | 28.14 | 25.29 | 46.66 | 36.66 | 40.00 | 41.11 | 50.00 | 60.00 | 46.66 | 52.22 | 16.72 | 16.32 | 16.29 | 16.44 |
| $M_2$ (silt) | 24.19 | 33.42 | 33.5 | 30.37 | 46.66 | 40.00 | 33.33 | 40.00 | 60.00 | 60.00 | 46.66 | 55.55 | 13.28 | 13.41 | 13.51 | 13.40 |
| $M_3$ (soil + cocopeat) | 26.59 | 30.22 | 30.29 | 29.03 | 53.33 | 36.66 | 50.00 | 46.66 | 70.00 | 66.66 | 56.66 | 64.44 | 19.47 | 20.55 | 19.36 | 19.79 |
| $M_4$ (soil + vermicompost) | 27.86 | 24.7 | 23.33 | 25.30 | 66.66 | 50.00 | 56.66 | 57.77 | 76.66 | 60.00 | 66.60 | 67.75 | 28.22 | 27.66 | 27.38 | 27.75 |
| $M_5$ (Silt + cocopeat) | 26.85 | 27.67 | 27.44 | 27.32 | 46.66 | 40.00 | 46.66 | 44.44 | 60.00 | 60.00 | 63.33 | 61.11 | 21.16 | 21.37 | 21.35 | 21.29 |
| $M_6$ (Silt + vermicompost) | 29.07 | 33.53 | 33.32 | 31.97 | 53.33 | 43.33 | 63.33 | 53.33 | 73.33 | 80.00 | 70.00 | 74.44 | 20.44 | 20.27 | 19.68 | 20.13 |
| $M_7$ (Soil + silt) | 24.58 | 24.27 | 24.22 | 24.36 | 56.66 | 53.33 | 50.00 | 53.33 | 66.66 | 60.00 | 66.66 | 64.44 | 21.65 | 22.26 | 22.3 | 22.07 |
| $M_8$ (Soil + silt +vermicompost) | 23.09 | 23.25 | 23.75 | 23.36 | 86.66 | 73.33 | 66.66 | 75.55 | 90.00 | 80.00 | 70.00 | 80.00 | 28.58 | 28.27 | 28.11 | 28.32 |
| $M_9$ (soil + silt +cocopeat) | 26.67 | 24.16 | 24.26 | 25.03 | 50.00 | 63.33 | 46.66 | 53.33 | 70.00 | 73.33 | 60.00 | 67.78 | 29.27 | 23.6 | 23.53 | 25.47 |
| Mean | 25.93 | 27.17 | 27.58 | - | 56.29 | 48.51 | 50.37 | - | 68.52 | 66.67 | 60.73 | - | 22.06 | 21.52 | 21.28 | - |
| **INTERACTION (M X T)** | | | | | | | | | | | | | | | | |
| | M | T | M X T | | M | T | M X T | | M | T | M X T | | M | T | M X T | |
| SE(M)± | 0.13 | 0.08 | 0.23 | | 2.86 | 1.65 | 4.96 | | 9.48 | 6.33 | 6.37 | | 0.12 | 0.07 | 0.2 | |
| CD at 5% | 0.39 | 0.22 | 0.68 | | 8.15 | 4.7 | 14.12 | | - | - | - | | 0.34 | 0.2 | 0.6 | |

**Table 2. Effect of different media and time of cutting on length, fresh weight, dry weight of root and root density.**

| Treatment | Length of root (cm) | | | | Root density (ml) | | | | Fresh weight of root (g) | | | | Dry weight of root (g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Time of cutting | | | | Time of cutting | | | | Time of cutting | | | | Time of cutting | | | |
| Media | $T_1$ (15th January) | $T_2$ (30th January) | $T_3$ (15th February) | Mean | $T_1$ (15th January) | $T_2$ (30th January) | $T_3$ (15th February) | Mean | $T_1$ (15th January) | $T_2$ (30th January) | $T_3$ (15th February) | Mean | $T_1$ (15th January) | $T_2$ (30th January) | $T_3$ (15th February) | Mean |
| $M_1$ (soil) | 9.19 | 9.18 | 9.17 | 9.18 | 13.14 | 12.67 | 12.31 | 12.71 | 2.1 | 1.68 | 1.43 | 1.74 | 0.84 | 0.76 | 0.89 | 0.83 |
| $M_2$ (silt) | 13.67 | 13.26 | 13.15 | 13.36 | 11.85 | 11.18 | 10.86 | 11.30 | 2.29 | 2.1 | 1.67 | 2.02 | 0.86 | 0.57 | 0.6 | 0.68 |
| $M_3$ (soil + cocopeat) | 12.54 | 12.59 | 14.46 | 13.20 | 13.34 | 13.32 | 13.13 | 13.26 | 1.36 | 1.33 | 1.35 | 1.35 | 0.31 | 0.26 | 0.34 | 0.30 |
| $M_4$ (soil + vermicompost) | 15.4 | 15.41 | 15.42 | 15.41 | 14.24 | 14.15 | 14.18 | 14.19 | 2.66 | 2.22 | 2.26 | 2.38 | 0.88 | 0.29 | 0.34 | 0.50 |
| $M_5$ (Silt + cocopeat) | 6.77 | 6.84 | 6.24 | 6.62 | 12.22 | 12.22 | 12.05 | 12.16 | 2.87 | 2.33 | 2.45 | 2.55 | 0.26 | 0.23 | 0.32 | 0.27 |
| $M_6$ (Silt + vermicompost) | 12.25 | 14.45 | 14.45 | 13.72 | 13.44 | 12.89 | 12.87 | 13.07 | 2.28 | 2.21 | 2.31 | 2.27 | 0.29 | 0.23 | 0.34 | 0.29 |
| $M_7$ (Soil + silt) | 12.54 | 12.38 | 12.64 | 12.52 | 11.92 | 11.89 | 11.73 | 11.85 | 2.44 | 2.08 | 2.04 | 2.19 | 0.77 | 0.34 | 0.33 | 0.48 |
| $M_8$ (Soil + silt +vermicompost) | 18 | 17.5 | 16 | 17.17 | 16.56 | 15.99 | 15.76 | 16.10 | 2.88 | 2.8 | 2.55 | 2.74 | 0.9 | 0.89 | 0.89 | 0.89 |
| $M_9$ (soil + silt +cocopeat) | 14.66 | 14 | 14 | 14.22 | 15.06 | 14.98 | 15.03 | 15.02 | 1.81 | 1.14 | 2.93 | 1.96 | 0.81 | 0.89 | 0.85 | 0.85 |
| Mean | 12.78 | 12.84 | 12.83 | - | 13.53 | 13.25 | 13.1 | - | 2.3 | 1.99 | 2.11 | - | 0.66 | 0.49 | 0.54 | - |
| **INTERACTION (M X T)** | | | | | | | | | | | | | | | | |
| | **M** | **T** | **M X T** | | **M** | **T** | **M X T** | | **M** | **T** | **M X T** | | **M** | **T** | **M X T** | |
| SE(M)± | 0.13 | 0.07 | 0.23 | | 0.11 | 0.06 | 0.08 | | 0.06 | 0.03 | 0.11 | | 0.02 | 0.03 | 0.03 | |
| CD at 5% | 0.38 | - | 0.66 | | 0.32 | 0.18 | - | | 0.19 | 0.11 | 0.33 | | 0.06 | 0.01 | 0.1 | |

season causes lesser growth of shoot might indirectly reflects more root growth.The findings are in agreement with Ansari (2013) in pomegranate.

**Effect of different rooting media and time of cutting on root density**

Significantly highest root density (16.10 ml) obtained from ($M_8$) cutting planted on soil + silt + vermicompost media. While minimum root density (11.30 ml) was obtained in ($M_2$) silt media (Table 2).

Whereas, significantly highest root density (13.53 ml) was observed in ($T_1$) cutting taken on 15thJanuary. However the lowest root density (13.10 ml) was obtained in ($T_3$) cutting taken on 30 January.

An interaction effect of different rooting media and time of cutting on root density was found to be non-significant.

This might be due to the fact that, rooting media content high C:N ratio, antifungal character and more spaces due to silt, vermicompost as the rooting media combination. Thus, increase the number of roots, resulting in maximum root density. Similar results were also observed by Ari (2016) in *Vitexagnus-castus* L.

**Effect of different media and time on fresh weight of roots**

The significant effect due to different media on fresh weight root in soil was recorded maximum fresh weight of root (2.74 g) was found in ($M_8$) Soil + Silt + Vermicompost media which was significantly superior over all treatments. However minimum fresh weight of root (1.35g) was found in ($M_3$) soil + cocopeat.

The data presented in Table 2, showed the significant effect due to different time of cutting on fresh weight of root**.** The maximum fresh weight of root (2.30 g) found in ($T_1$) cutting taken on 15 January. However minimum fresh weight of root (1.99 g) was found in ($T_2$) cutting taken on 30 January.

An interaction effect of different rooting media and time of cutting on fresh weight of root were also found to be significant. The maximum fresh weight of root (2.88g) was found in treatment combination ($M_8T_1$) soil + silt + vermicompost media and cutting taken on 15thJanuary. While the minimum fresh weight of root (1.14 g) noticed in treatment combination ($M_9T_2$) soil + silt + cocopeat media and cutting taken on 30 January.

The increases in number of roots and length of roots have directly influenced the fresh weight of roots. These results are in close conformity with Waheb *et al.* (2011) in guava and Khajehpour *et al.* (2014) in olive.

**Effect of different media and time of cutting on dry weight of root**

Significantly, maximum dry weight of root (0.89 g) noted in ($M_8$) soil + silt + vermicompost media. However the minimum dry weight of root (0.27g) was found in ($M_5$) silt + cocopeat. Dry weight of accumulation in roots significantly differ among the rootingmedia.

The data presented in Table 2 also showed the significant effect due to different time of cutting on dry weight of root. The maximum dry weight of root (0.66 g) found in ($T_2$) cutting taken on 15thJanuary. While minimum dry weight of root (0.49 g) was observed in ($T_1$) cutting taken on 30 January. The results are in conformity with those of Khajehpour *et al.* (2014) in olive, Singh and Nair (2003) in phalsa.

The treatment combination ($M_8T_1$) soil + silt + vermicompost media and cutting taken on 15January recorded significantly maximum dry weight of root (0.90 g), whereas the minimum dry weight of root (0.23 g) was found in treatment combination ($M_5T_2$) Silt + cocopeat media and cutting taken on 30 January.

It might be due to lacuna of one media may be compensated by the characteristic property of other media. As soil has poor drainage properties might have compensated by good aeration and porosity character of silt and vermicompost. The results are in agreement with the earlier findings of Kaur *et al.* (2016) in grapevine and Ajaiumar *et al.* (2011) in patchouli cuttings.

**Effect of different rooting media and time of cutting on nitrogen uptake of content by cutting**

The significant effect due to different media on nitrogen contain by cutting was noticed. The maximum nitrogen uptake by cutting (1.94 %) was noted in ($M_8$) in soil + silt + vermicompost media, while minimum nitrogen contain by cutting (0.59 %) was noted in ($M_1$) cutting planted in soil media (Table 3).

**Table 3. Effect of different media and time of cutting on Nitrogen, Phosphorus and Potassium uptake by cutting**

| Treatment | Nitrogen uptake by cutting % | | | | Phosphorus uptake by cutting % | | | | Potasssium uptake by cutting % | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Time of cutting | | | | Time of cutting | | | | Time of cutting | | | |
| Media | $T_1$ (15th January) | $T_2$ (30th January) | $T_3$ (15th February) | Mean | $T_1$ (15th January) | $T_2$ (30th January) | $T_3$ (15th February) | Mean | $T_1$ (15th January) | $T_2$ (30th January) | $T_3$ (15th February) | Mean |
| $M_1$ (soil) | 1.62 | 1.58 | 1.56 | 1.59 | 2.35 | 2.35 | 2.3 | 2.33 | 2.03 | 2.12 | 2.13 | 2.09 |
| $M_2$ (silt) | 0.63 | 0.62 | 0.62 | 0.62 | 2.2 | 1.99 | 2.25 | 2.15 | 1.19 | 1.18 | 1.18 | 1.18 |
| $M_3$ (soil + cocopeat) | 1.63 | 1.62 | 1.63 | 1.63 | 2.32 | 2.63 | 2.88 | 2.61 | 1.81 | 1.79 | 1.76 | 1.79 |
| $M_4$ (soil + vermicompost) | 1.66 | 1.64 | 1.63 | 1.64 | 4.01 | 4.2 | 3.4 | 3.87 | 1.68 | 1.67 | 1.67 | 1.67 |
| $M_5$ (Silt + cocopeat) | 0.97 | 0.93 | 0.92 | 0.94 | 3.36 | 2.21 | 3.26 | 2.94 | 1.35 | 1.32 | 1.31 | 1.33 |
| $M_6$ (Silt + vermicompost) | 0.95 | 0.94 | 0.93 | 0.94 | 9.22 | 8.86 | 8.7 | 8.93 | 1.34 | 1.34 | 1.31 | 1.33 |
| $M_7$ (Soil + silt) | 1.66 | 1.64 | 1.63 | 1.64 | 3.62 | 2.21 | 3.26 | 3.03 | 2.11 | 2.04 | 1.18 | 1.78 |
| $M_8$ (Soil + silt +vermicompost) | 1.97 | 1.94 | 1.92 | 1.94 | 7.02 | 4.4 | 5.74 | 5.72 | 2.13 | 2.11 | 2.12 | 2.12 |
| $M_9$ (soil + silt +cocopeat) | 1.74 | 1.75 | 1.66 | 1.72 | 2.35 | 2.2 | 2.16 | 2.24 | 1.88 | 1.77 | 1.73 | 1.79 |
| Mean | 1.42 | 1.4 | 1.39 | - | 4.02 | 3.57 | 3.75 | - | 1.72 | 1.7 | 1.6 | - |
| **INTERACTION (M XT)** | | | | | | | | | | | | |
| | **M** | **T** | **M X T** | | **M** | **T** | **M X T** | | **M** | **T** | **M X T** | |
| | 0.005 | 0.003 | 0.009 | | 0.002 | 0.001 | 0.004 | | 0.006 | 0.004 | 0.011 | |
| CD at 5% | 0.014 | 0.008 | 0.025 | | 0.007 | 0.004 | 0.012 | | 0.018 | 0.011 | 0.032 | |

The significant effect of different time of cutting on nitrogen contain cutting was recorded and the maximum nitrogen contain in cutting (1.42 %) was noted in ($T_1$) cutting taken on 15th January, while minimum nitrogen contain by cutting (1.39 %) was found in ($T_3$) cutting taken on 15th February.

The high C: N ratio is observed in cutting taken in early January which results into maximum availability of plant nutrients.The findings are in agreement with earlier researchers like Kasim *et al.* (2009) in bitter almond cuttings.

An interaction effect of different rooting media and time of cutting on nitrogen contain by cutting was also found significant. The maximum nitrogen contain by cutting (1.97per cent) was observed in treatment combination ($M_8T_1$) soil + silt + vermicompost media and cutting taken on 15thJanuary, While minimum nitrogen contain by cutting (0.62 %) was found in treatment combination ($M_1T_3$) soil media and cutting taken on 15th February.

**Effect of different media and time of cutting on phosphorus uptake by cutting**

Significantly maximum phosphorus contain by cutting (8.93 %) was observed in ($M_6$) silt + vermicompost media, while minimum phosphorus uptake by cutting (2.15 %) was found in ($M_2$) silt media (Table 3).

The significant effect due to different time of cutting on phosphorus contain in cutting was observed and the maximum phosphorus contain in cutting (4.02 %) was observed in ($T_1$) cutting taken on 15th January, while the minimum phosphorus contain (3.57%) was observed in ($T_2$) cutting taken on 30th January.

An interaction effect of different rooting media and time of cutting on phosphorus contain in cutting was found significant and maximum phosphorus contain in cutting (8.86 %) observed in treatment combination ($M_6T_2$) silt + vermicompost media and cutting taken on 15th January, while minimum phosphorus contain (1.99 %) in cutting was found in treatment combination ($M_2T_2$) silt media and cutting taken on 30th January (Table 3).

The above findings are in close agreement with Bemkairemia *et al.* (2012) in Passionfruit.

**Effect of different media and time of cutting potassium contain incutting**

The significant effect of different media on potassium contain in cutting was observed and maximum potassium contain in cutting (2.12 %) was observed in ($M_8$) soil + silt + vermicompost, while minimum phosphorus contain (1.18 %) by cutting was found in ($M_2$) silt media.

The effect of different time of cutting on potassium contain in cutting was maximum potassium contain in cutting (1.72 %) observed in ($T_1$) cutting taken on 15th January, while minimum potassium contain by cutting (1.60 %) was found in ($T_3$) cutting taken on 15th February.

An interaction effect of different rooting media and time of cutting on potassium contain in cutting was found to be significant. The maximum potassium contain in cutting (2.13per cent) observed in treatment combination ($M_8T_1$) soil + silt + vermicompost media and cutting taken on 15thJanuary and ($M_1T_3$) soil media and cutting on 15th February, while the minimum potassium contain in cutting (1.18 %) observed in treatment combination ($M_2T_2$) silt media and cutting taken on 30th January and ($M_2T_3$) silt media and cutting taken on 15th February.

The maximum availability of organic compounds in the soil + silt + vermicompost media results into greater amount of nutrient uptake through maximum number of roots. The above findings are in close agreement with Bemkairemia *et al.* (2012) in passion fruit.

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# Root Biomass and Quality of *Gmelina arborea* - a Species of Brihatpanchmool as Influenced by Plant Geometry and Organic Manure

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**ABSTRACT**

To assess the growth and root yield performance of Gambhari/Shivan a tree species was planted under different geometry and soil fertility during *Kharif* season of 2008-09 the treatments comprising of three plant spacings 100 x 150 cm (S1-6,666 Plant population $ha^{-1}$),100 x 100 cm (S2-10,000 Plant population $ha^{-1}$) ,100 x 50 cm (S3-20,000 Plant population $ha^{-1}$) and four levels viz.0.0(F1), 2.0(F2) ,4.0(F3) ,6.0(F4) t $ha^{-1}$.with the plot size of 6.0 x 6 .0 m. The observations on plant height, No. of branches, root length and girth, fresh and dry root yield were recorded up to 3 years at an interval of six months growth period. The plants of Gambhari *(Gmelina arborea)*, were completely uprooted at 6, 12 and 18 month's growth period for recording the root yield including tap root. The woody and hard tap root is rather less pharmaceutical important and therefore at 24, 30 and 36 months growth period only lateral roots were harvested. Plant height, root length, root girth and dry root yield per plant of Gambhari was highest with the plant spacing of 100 x 150 cm and FYM @ 2 t $ha^{-1}$ (S1xF2) after 6 months of growth period. The per cent WSE values were very high with spacing of 150x100 cm (S1) and 100x100 cm (S2) than 100x50 cm (S3) without much difference with FYM levels i.e 0 t (F1) & 2.0 t (F2).

At 12 months of growth period, the number of branches, root length, root girth and dry root yield per plant and total alkaloids were highest with the plant spacing of 100 x 150 cm and FYM @ 2 t $ha^{-1}$ (S1xF2). The per cent WSE values however were less than required (20 %) by Ayurvedic Pharmacopoeial Standards with all the treatments. After 18 months growth period, highest no of branches, root length, root girth dry root yield, per cent WSE and total glycosides were observed, with the plant spacing of 100 x 150 cm and FYM @ 2 t $ha^{-1}$ (S1xF2). The dry root yield per plant (991 g) was highest amongst all the other treatments. Total alkaloids, total phenols and total flavonoids were highest with plant spacing of 100x100 cm with FYM @ 2 t $ha^{-1}$ (S2xF2). Since the harvesting of roots after 18 months was very difficult with increased requirement of labour, time and cost, lateral roots were harvested from 24 months and analysed. At 24 months stage, the root girth, dry root yield per plant, total alkaloids and total phenols were highest with S1x F2, while per centWSE and per cent ASE were slightly lower (22.78 & 12.48 %) than the highest which were observed with 100 x100 cm plant spacing (24.06 & 14.14 % ). At 30 and 36 months age, the values of per cent WSE, were less than at 18 and 24 month and also much less than the standard pharmacopoeial requirement i.e 20 per cent with all the treatments.

Many of the manufacturing units of Ayurvedic drugs are experiencing the shortage of raw material for the plant products from medicinal plant species being used as a Dashmool. The supply of the raw material particularly to that of root based material from trees of dashmool group is very-very meagre and hardly there are reliable data available which support supply scenario. This kind of short supply may lead to the use of either substitutes or in a very low quantity in the ayurvedic formulations and ultimately affect the efficacy of the formulations. In view of above, it is imperative to develop the agrotechnologies of these species. Hence, there is an urgent need for an intervention to develop and conserve the resource base for dashmool.

The present investigation was carried out with the objectives to develop the agronomic protocols for high density, short term plantation for Gambhari/Shivan (*Gmelina arborea*) a species of Brihatpanchmool and to study the yielding potential as influenced by age of the plant and time of harvesting.

Dashmoola is a fixed dose combination of 10 roots obtained from *Aegle marmelos* (Tree), *Gmelina arborea* (Tree), *Oroxylum indicum* (Tree), *Stereospermum suaveolens* (Tree) Clerodendron *multiflorum* (Shrub), *Desmodium gangeticum* (Herb), *Uraria picta* (under shrub) *Solanum indicum* (Shrub), *Solanum xanthocarpum* (Herb), *Tribulus terristeries (*Herb). Habit-

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wise, it includes 5 tree species, 2 shrub / under shrub species and 3 herb species. These species belong to six different families of Angiosperms: Verbenaceae (2 species), Fabaceae (2 species), Solanaceae (2 species), Bignoniaceae (2 species), Rutaceae (1 species) and Zygophyllaceae (1 species).

Dashmoola is indicated for aggravations of the nervous system and pain when there are signs of debility. It is used as a decoction or enema for lower back pain, sciatica, tremors, Parkinson's disease and inflammation in the pelvic and sacral region. For dry cough and respiratory weakness when there is high *vata* Dashmoolarisht can be used as a tonic to strengthen the system. When the immune system is depleted and is not throwing off fevers the decoction can cause diaphoresis and release the trapped *ama* toxins. It is also good for influenza, colds, neuralgia, and headaches. One-quarter cup consumed daily for twenty-one days functions as a rapid cell rejuvenator.

## MATERIAL AND METHODS

To assess the growth and root yield performance of Gambhari/Shivan a tree species was planted under different geometry and soil fertility during *Kharif* season 2008-09 the treatments comprising of three plant spacings 100 x 150 cm ($S_1$ 6,666 Plant population $ha^{-1}$),100 x 100 cm ($S_2$ 10,000 Plant population $ha^{-1}$) ,100 x 50 cm ($S_3$ 20,000 Plant population $ha^{-1}$) and four levels viz.0.0 ,2.0 ,4.0 ,6.0 t $ha^{-1}$.with the plot size of 6.0 x 6 .0 m. The observations on plant height, No. of branches, root length and girth , fresh and dry root yield were recorded up to 3 years at an interval of six months growth period. The plants of Gambhari *(Gmelina arborea)*, were completely uprooted at 6, 12 and 18 month's growth period for recording the root yield including tap root. The woody and hard tap root is rather less pharmaceutical important and therefore at 24, 30 and 36 months growth period only lateral roots were harvested. The physicochemical and phyto-chemical analysis of the roots harvested at 6, 12, 18, 24, 30 and 36 months growth period was carried out.by standard methods ( Torel, *et al*,1986 ; Agrawal and Paridhavi,2007 and Padma,*et al*.,2010 ).

## RESULTS AND DISCUSSION

### Plant height

Significantly maximum plant height was recorded with the closer plant spacing 100 x 50 cm except the plant height recorded at 30 and 36 months and was highest with the plant spacing of 100 x 100 cm, however it was at par with the closer spacing of 100 x 50 cm.(Table 1).

Application of FYM at various levels significantly influenced the plant height and significantly maximum plant height was noticed with the application 6 t FYM per hectare at all the growth period under study except the plant height recorded at 24 months growth period. It was significantly highest with the application of 2 t FYM per hectare. The interaction effect was found to be significant at all the growth periods. The plant spacing of 100 x 50 cm with the application of 6 t FYM per hectare (S3xF4) recorded significantly maximum plant height at all the growth period except 24 and 36 months growth periods. The plant height noticed at 24 and 36 months growth periods under the plant spacing 100 x 100 cm with 6 t FYM per hectare (S2 x F4) was significantly highest.

### No. of branches:

The number of branches was also successively found to increase with each growth period and it was noticed that significantly maximum number of branches were recorded with the wider plant spacing 100 x 150 cm except the branches recorded at 36 months growth period and were maximum with the plant spacing of 100 x 100 cm (Table-2).

Application of FYM at various levels significantly influenced the number of branches $plant^{-1}$ and significantly maximum branches were noticed with the application 6 t FYM $ha^{-1}$ at all the growth period under study. The interaction effect was found to be significant at all the growth periods. The plant spacing of 100 x 150 cm with the application of 6 t FYM $ha^{-1}$ (S1xF4) recorded significantly maximum branches $plant^{-1}$. However, number of branches noticed at 36 months growth periods under the plant spacing 100 x 100 cm with 6 t FYM $ha^{-1}$ (S2xF4) was significantly highest.

### Root length and girth

The data presented in Table 3(a) revealed that the root length and girth of completely uprooted plants of Shivan at 6, 12 and 18 months growth periods were successively found to increase with each growth period.

**Table 1. Relative plant height of Gambhari/Shivan (*Gmelina arborea*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | | | |
|---|---|---|---|---|---|---|
| | 6 | 12 | 18 | 24 | 30 | 36 |
| **Plant spacing (cm)** | | | **Plant Height (cm)** | | | |
| S1-(100 X 150 ) | 46.94 | 101.54 | 232.97 | 342.81 | 372.50 | 443.74 |
| S2-(100 X 100 ) | 50.23 | 107.71 | 251.50 | 350.25 | **470.25** | **548.75** |
| S3-(100 X 50 ) | 60.59 | 110.63 | 258.18 | 357.29 | 469.89 | 538.97 |
| SE (m) ± | 0.77 | 1.59 | 1.63 | 3.50 | 16.32 | 10.94 |
| CD at 5% | 2.26 | 4.67 | 4.78 | 10.26 | 47.89 | 32.11 |
| | | | **FYM levels (t $ha^{-1}$)** | | | |
| F 1 -0.0 | 44.72 | 94.78 | 226.22 | 325.78 | 353.33 | 469.44 |
| F 2 -2.0 | 49.61 | 102.97 | 250.91 | **362.25** | 456.86 | 504.86 |
| F 3 -4.0 | 52.78 | 113.21 | 254.80 | 357.19 | 460.25 | 510.19 |
| F 4 -6.0 | 63.23 | 115.55 | 258.27 | 355.25 | 479.75 | 557.46 |
| SE (m) ± | 0.89 | 1.84 | 1.88 | 4.04 | 18.85 | 12.64 |
| CD at 5% | 2.61 | 5.39 | 5.53 | 11.85 | 55.29 | 37.08 |
| | | | **Interaction S x F** | | | |
| S1F1 | 31.75 | 88.67 | 209.16 | 308.75 | 337.50 | 391.25 |
| S1F2 | 46.50 | 97.75 | 236.25 | 355.00 | 376.25 | 443.33 |
| S1F3 | 50.00 | 108.75 | 240.00 | 382.50 | 396.25 | 452.91 |
| S1F4 | 59.50 | 111.00 | 246.50 | 325.00 | 380.00 | 487.50 |
| S2F1 | 41.00 | 95.67 | 229.67 | 302.00 | 390.83 | 515.83 |
| S2F2 | 47.00 | 104.33 | 254.50 | 342.00 | 497.67 | 543.33 |
| S2F3 | 50.33 | 113.17 | 260.00 | 355.83 | 475.00 | 539.17 |
| S2F4 | 62.60 | 117.67 | 261.83 | **401.17** | 517.50 | **596.67** |
| S3F1 | 61.42 | 100.00 | 239.83 | 366.58 | 331.67 | 501.25 |
| S3F2 | 55.33 | 106.83 | 262.00 | 389.75 | 496.67 | 527.92 |
| S3F3 | 58.00 | 117.71 | 264.40 | 333.25 | 509.50 | 538.50 |
| S3F4 | 67.60 | 118.00 | 266.49 | 339.58 | 541.75 | 588.22 |
| SE (m) ± | 1.54 | 3.18 | 3.26 | 6.996 | 32.65 | 21.89 |
| CD at 5% | 4.52 | 9.34 | 9.57 | 20.52 | 95.78 | 64.22 |

Further, it was noticed that significantly maximum root length and girth was recorded with the wider plant spacing 100 x 150 cm, except the root length recorded at 6 months and was highest with the plant spacing of 100 x 100 cm, however it was at par with the spacing of 100 x 150 cm.

Application of FYM at various levels significantly influenced the root length and girth and significantly maximum root length and root girth was noticed with the application 6 t FYM per hectare at all the growth period under study.The interaction effect was found to be significant at all the growth periods. The plant spacing of 100 x 150 cm with the application of 6 t FYM $ha^{-1}$ (S1 x F4) recorded significantly maximum root length and girth at all the growth period except 6 months growth periods. The root length and girth noticed at 6 months growth periods under the plant spacing 100 x 100 cm with 6 t FYM $ha^{-1}$ (S2 x F4) was significantly highest, however at par under plant spacing of 100 x 150 cm with the application of 6 t FYM per hectare (S1 x F4).

During the growth periods of 24, 30 and 36 months

**Table 2 : Relative number of branches of Gambhari/Shivan (*Gmelina arborea*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | | | |
|---|---|---|---|---|---|---|
| | 6 | 12 | 18 | 24 | 30 | 36 |
| **Plant spacing (cm)** | | | No. of branches | | | |
| S1-(100 X 150 ) | 3.43 | 7.60 | 8.20 | 11.21 | 17.61 | 18.54 |
| S2-(100 X 100 ) | 2.93 | 7.00 | 6.48 | 10.06 | 16.50 | 21.20 |
| S3-(100 X 50 ) | 2.64 | 6.05 | 4.62 | 9.13 | 10.25 | 18.07 |
| SE (m) ± | 0.06 | 0.19 | 0.13 | 0.25 | 0.35 | 0.60 |
| CD at 5% | 0.18 | 0.57 | 0.41 | 0.75 | 1.03 | 1.76 |
| **FYM levels (t ha$^{-1}$)** | | | | | | |
| F 1 -0.0 | 2.94 | 6.19 | 5.75 | 8.61 | 10.36 | 14.49 |
| F 2 -2.0 | 2.66 | 6.88 | 6.13 | 9.69 | 14.09 | 18.23 |
| F 3 -4.0 | 3.16 | 6.94 | 6.87 | 10.70 | 16.28 | 20.86 |
| F 4 -6.0 | 3.25 | 7.51 | 6.98 | 11.53 | 18.41 | 23.48 |
| SE (m) ± | 0.07 | 0.22 | 0.16 | 0.29 | 0.40 | 0.69 |
| CD at 5% | 0.21 | 0.66 | 0.47 | 0.86 | 1.19 | 2.03 |
| **Interaction S x F** | | | | | | |
| S1F1 | 3.25 | 6.67 | 6.75 | 9.50 | 11.08 | 14.66 |
| S1F2 | 3.50 | 7.75 | 7.50 | 10.50 | 16.70 | 18.50 |
| S1F3 | 3.50 | 8.00 | 9.33 | 11.67 | 19.17 | 19.00 |
| S1F4 | **3.50** | **8.00** | **9.25** | **13.17** | **23.50** | 22.00 |
| S2F1 | 3.00 | 6.00 | 6.17 | 8.33 | 12.00 | 13.83 |
| S2F2 | 2.50 | 7.33 | 6.33 | 9.58 | 15.83 | 20.80 |
| S2F3 | 3.00 | 6.67 | 6.60 | 10.92 | 18.17 | 23.50 |
| S2F4 | 3.25 | 8.00 | 6.83 | 11.42 | 20.00 | **26.67** |
| S3F1 | 2.58 | 5.91 | 4.33 | 8.00 | 8.00 | 15.00 |
| S3F2 | 2.00 | 5.58 | 4.58 | 9.00 | 9.75 | 15.40 |
| S3F3 | 3.00 | 6.17 | 4.70 | 9.50 | 11.50 | 20.10 |
| S3F4 | 3.00 | 6.55 | 4.88 | 10.00 | 11.75 | 21.78 |
| SE (m) ± | 0.12 | 0.39 | 0.27 | 0.51 | 0.70 | 1.20 |
| CD at 5% | 0.37 | 1.14 | 0.82 | 1.49 | 2.06 | 3.53 |

only lateral roots were harvested and the data generated on the lateral root length and girth is presented in Table-3(b). The lateral root length and girth was also successively found to increase with each growth period. Further, it was noticed that significantly maximum root length and girth was recorded with the wider plant spacing 100 x 150 cm.

Application of FYM at various levels significantly influenced the root length and girth and significantly maximum root length and root girth was noticed with the application 6 t FYM ha$^{-1}$ at all the growth period (24, 30 and 36 months) under study.The interaction effect was found to be significant at all the growth periods. The plant spacing of 100 x 150 cm with the application of 6 t FYM ha$^{-1}$ (S1xF4) recorded significantly maximum root length and girth at all the growth period, except root girth recorded at 12 and 18 months growth period.

**Table-3 (a) Relative root length and girth of completely uprooted plants of Gambhar/Shivan (*Gmelina arborea*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | | | |
|---|---|---|---|---|---|---|
| | 6 | 12 | 18 | 6 | 12 | 18 |
| **Plant spacing (cm)** | | **Root length (cm)** | | | **Root girth (cm)** | |
| S1-(100 X 150 ) | 20.81 | 31.48 | 83.63 | 1.16 | 2.25 | 4.64 |
| S2-(100 X 100 ) | 21.58 | 25.71 | 78.94 | 1.07 | 1.94 | 4.61 |
| S3-(100 X 50 ) | 19.87 | 25.04 | 66.31 | 0.98 | 1.53 | 4.39 |
| SE (m) ± | 0.59 | 0.56 | 0.72 | 0.03 | 0.02 | 0.05 |
| CD at 5% | 1.75 | 1.64 | 2.14 | 0.09 | 0.05 | 0.16 |
| | | | **FYM levels (t ha$^{-1}$)** | | | |
| F 1 -0.0 | 20.05 | 25.72 | 74.52 | 0.98 | 1.47 | 4.17 |
| F 2 -2.0 | 20.42 | 26.67 | 75.78 | 1.04 | 1.65 | 4.64 |
| F 3 -4.0 | 20.83 | 28.16 | 77.01 | 1.10 | 1.72 | 4.67 |
| F 4 -6.0 | 21.71 | 29.05 | 77.86 | 1.16 | 2.78 | 4.69 |
| SE (m) ± | 0.69 | 0.65 | 0.84 | 0.03 | 0.02 | 0.06 |
| CD at 5% | 2.02 | 1.89 | 2.47 | 0.10 | 0.60 | 0.18 |
| | | | **Interaction S x F** | | | |
| S1F1 | 20.25 | 28.67 | 80.50 | 1.00 | 1.67 | 4.30 |
| S1F2 | 20.50 | 30.75 | 82.75 | 1.15 | 2.13 | 4.73 |
| S1F3 | 20.75 | 32.50 | 85.25 | 1.23 | 2.18 | 4.75 |
| S1F4 | 21.75 | 34.00 | 86.00 | 1.28 | 3.03 | 4.75 |
| S2F1 | 20.75 | 24.17 | 77.83 | 1.00 | 1.52 | 4.18 |
| S2F2 | 21.33 | 24.83 | 78.33 | 1.00 | 1.58 | 4.72 |
| S2F3 | 21.67 | 26.50 | 79.29 | 1.07 | 1.72 | 4.75 |
| S2F4 | 22.60 | 27.33 | 80.33 | 1.22 | 2.93 | 4.77 |
| S3F1 | 19.17 | 24.33 | 65.25 | 0.95 | 1.23 | 4.04 |
| S3F2 | 19.44 | 24.42 | 66.25 | 0.97 | 1.24 | 4.47 |
| S3F3 | 20.08 | 25.57 | 66.50 | 1.00 | 1.27 | 4.51 |
| S3F4 | 20.80 | 25.82 | 67.25 | 1.00 | 2.37 | 4.54 |
| SE (m) ± | 1.19 | 1.12 | 1.46 | 0.06 | 0.04 | 0.11 |
| CD at 5% | 3.51 | 3.28 | 4.27 | 0.18 | 0.11 | 0.31 |

**Root yield**

The data presented in Table-4(a) revealed that the dry root yield of completely uprooted plants of Shivan at 6, 12 and 18 months growth periods was found to increase markedly with each growth period. The root yield was in the range of 0.23-0.74 q ha$^{-1}$at 6 months, 4.27-5.22 q ha$^{-1}$ at 12 months and 49.51-94.28 q ha$^{-1}$ at 18 months growth period. Further, it was noticed that significantly highest root yield was recorded with the closer plant spacing 100 x 50 cm.

Application of FYM at various levels significantly influenced the dry root yield and significantly maximum root yield was noticed with the application 6 t FYM per hectare, however it was at par with the

**Table-3 (b) Lateral root length and girth of Gambhar/Shivan (*Gmelina arborea*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | | | |
|---|---|---|---|---|---|---|
| | 24 | 30 | 36 | 24 | 30 | 36 |
| **Plant spacing (cm)** | | **Root length (cm)** | | | **Root girth (cm)** | |
| S1-(100 X 150 ) | 67.14 | 70.53 | 74.21 | 0.67 | 0.98 | 1.06 |
| S2-(100 X 100 ) | 66.69 | 67.94 | 70.73 | 0.62 | 0.88 | 0.95 |
| S3-(100 X 50 ) | 53.45 | 66.79 | 67.45 | 0.57 | 0.85 | 0.91 |
| SE (m) ± | 0.52 | 1.09 | 1.14 | 0.01 | 0.01 | 0.02 |
| CD at 5% | 1.52 | 3.20 | 3.35 | 0.02 | 0.04 | 0.06 |
| **FYM levels (t ha$^{-1}$)** | | | | | | |
| F 1 -0.0 | 54.85 | 60.89 | 65.57 | 0.54 | 0.70 | 0.89 |
| F 2 -2.0 | 58.44 | 64.24 | 67.91 | 0.65 | 0.87 | 0.98 |
| F 3 -4.0 | 64.61 | 70.25 | 71.28 | 0.63 | 1.00 | 0.99 |
| F 4 -6.0 | 71.79 | 78.29 | 74.43 | 0.65 | 1.03 | 1.01 |
| SE (m) ± | 0.60 | 1.26 | 1.14 | 0.01 | 0.02 | 0.02 |
| CD at 5% | 1.76 | 3.69 | 3.35 | 0.02 | 0.05 | 0.60 |
| **Interaction S x F** | | | | | | |
| S1F1 | 56.13 | 59.38 | 70.13 | 0.59 | 0.71 | 1.01 |
| S1F2 | 56.13 | 65.75 | 70.17 | 0.73 | 1.06 | 1.08 |
| S1F3 | 72.53 | 72.00 | 71.80 | 0.64 | 1.11 | 1.10 |
| S1F4 | 83.75 | 85.00 | 84.75 | 0.73 | 1.04 | 1.04 |
| S2F1 | 60.92 | 63.75 | 64.58 | 0.55 | 0.70 | 0.83 |
| S2F2 | 68.00 | 66.17 | 69.83 | 0.63 | 0.81 | 0.97 |
| S2F3 | 68.00 | 66.83 | 73.25 | 0.61 | 1.02 | 0.99 |
| S2F4 | 69.83 | 75.00 | 75.25 | 0.70 | 0.98 | 1.00 |
| S3F1 | 47.50 | 59.54 | 62.00 | 0.49 | 0.70 | 0.85 |
| S3F2 | 51.20 | 60.80 | 63.73 | 0.60 | 0.75 | 0.89 |
| S3F3 | 53.29 | 71.92 | 68.80 | 0.65 | 0.89 | 0.89 |
| S3F4 | 61.79 | 74.88 | 75.28 | 0.53 | 1.06 | 1.00 |
| SE (m) ± | 1.04 | 2.18 | 2.28 | 0.01 | 0.03 | 0.40 |
| CD at 5% | 3.04 | 6.40 | 6.69 | 0.04 | 0.09 | 0.12 |

application 4 t FYM per hectare at all the growth period under study.The interaction effect was found to be significant at all the growth periods. The plant spacing of 100 x 50 cm with the application of 6 t FYM ha$^{-1}$ (S3xF4) recorded significantly maximum dry root yield at all the growth period, however at par with plant spacing of 100 x 50 cm the application of 4 t FYM ha$^{-1}$ (S3xF4).

During the growth periods of 24, 30 and 36 months only lateral roots were harvested and the data generated on the lateral root yield is presented in Table 4(b). The lateral root yield was also successively found to increase with each growth period. The root yield was in the range of 8.04-11.66 q ha$^{-1}$ at 24 months, 15.10-26.02 q ha$^{-1}$ at 30 months and 17.13-45.44 q ha$^{-1}$ at 36 months growth period. Further, it was noticed that significantly highest root yield was recorded with the plant spacing 100 x 100 cm.

**Table- 4 (a) Relative dry root yield of completely uprooted plants of Gambhari/Shivan (*Gmelina arborea*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | | | |
|---|---|---|---|---|---|---|
| | 6 | 12 | 18 | 6 | 12 | 18 |
| **Plant spacing (cm)** | Dry root yield (g plant$^{-1}$) | | | Dry root yield (q ha$^{-1}$) | | |
| S1-(100 X 150 ) | 5.47 | 71.73 | 980.00 | 0.36 | 4.79 | 65.39 |
| S2-(100 X 100 ) | 4.55 | 45.48 | 779.25 | 0.45 | 4.55 | 77.99 |
| S3-(100 X 50 ) | 3.31 | 24.70 | 459.25 | 0.66 | 4.94 | 91.92 |
| SE (m) ± | 9.68 | 0.71 | 24.09 | 0.01 | 0.08 | 2.73 |
| CD (P=0.05) | 0.28 | 2.09 | 70.65 | 0.03 | 0.26 | 7.99 |
| **FYM levels (t ha$^{-1}$)** | | | | | | |
| F 1 -0.0 | 3.17 | 42.38 | 636.33 | 0.37 | 4.28 | 70.15 |
| F 2 -2.0 | 4.07 | 46.46 | 744.67 | 0.44 | 4.66 | 78.85 |
| F 3 -4.0 | 4.63 | 49.19 | 783.00 | 0.52 | 4.94 | 82.13 |
| F 4 -6.0 | 5.90 | 51.20 | 794.00 | 0.63 | 5.14 | 82.60 |
| SE (m) ± | 0.11 | 0.82 | 27.81 | 0.01 | 0.10 | 3.14 |
| CD (P=0.05) | 0.32 | 2.41 | 81.56 | 0.04 | 0.30 | 9.23 |
| **Interaction S x F** | | | | | | |
| S1F1 | 3.50 | 64.00 | 742.00 | 0.23 | 4.27 | 49.51 |
| S1F2 | 5.38 | 70.67 | 991.00 | 0.36 | 4.72 | 66.12 |
| S1F3 | 5.75 | 75.25 | 1074.00 | 0.38 | 5.02 | 71.66 |
| S1F4 | 7.25 | 77.00 | 1113.00 | 0.48 | 5.14 | 74.26 |
| S2F1 | 3.15 | 40.33 | 726.00 | 0.31 | 4.04 | 72.66 |
| S2F2 | 3.83 | 44.50 | 783.00 | 0.38 | 4.45 | 78.36 |
| S2F3 | 4.50 | 46.60 | 804.00 | 0.45 | 4.66 | 80.46 |
| S2F4 | 6.75 | 50.50 | 804.00 | 0.67 | 5.05 | 80.46 |
| S3F1 | 2.88 | 22.80 | 441.00 | 0.57 | 4.56 | 88.27 |
| S3F2 | 3.00 | 24.20 | 460.00 | 0.60 | 4.84 | 92.07 |
| S3F3 | 3.64 | 25.71 | 471.00 | 0.73 | 5.15 | 94.28 |
| S3F4 | 3.72 | 26.10 | 465.00 | 0.74 | 5.22 | 93.07 |
| SE (m) ± | 0.19 | 1.42 | 48.18 | 0.02 | 0.18 | 5.45 |
| CD (P=0.05) | 0.56 | 4.18 | 141.31 | 0.07 | 0.53 | 15.99 |

Application of FYM at various levels significantly influenced the root yield and significantly highest root yield was noticed with the application 6 t FYM ha$^{-1}$ at all the growth period under study.The interaction effect was found to be significant at all the growth periods. The plant spacing of 100 x 150 cm with the application of 6 t FYM ha$^{-1}$ (S1xF4) recorded significantly highest root yield at 24 months growth period. Whereas the plant spacing of 100 x 150 cm with the application of 4 t FYM ha$^{-1}$ (S1xF3) recorded significantly highest root yield at 30 months growth period and the plant spacing of 100 x 100 cm with the application of 6 t FYM ha$^{-1}$ (S2xF4) recorded significantly highest root yield at 36 months growth period. These results are supported by the findings of Mohit Kumar and Rajesh Kumar (2013) and Adegun and Ayodele (2015). The application of organic manures influences the plant growth by enhancing root biomass thereby total root surface facilitates higher absorption of nutrients ultimately increase the biomass yield (Farhad *et al*, 2019).

**Physicochemical analysis of roots of Gambhari/Shivan (*Gmelina arborea*) as influenced by plant spacing and FYM levels.**

The data on physico and phyto-chemical parameters of roots of Gambhari/Shivan (*Gmelina arborea*) are presented in Table-5-7.

The data on water soluble extractive values revealed that the various plant spacing had influenced the WSE and highest values of WSE were noticed with wider spacing i.e. planting at 100 x 150 cm. The manurial treatments i.e. application of different levels of Farm Yard Manure under the plant spacing of 100 x 150 and 100 x 50 cm recorded favourable effect on WSE, however the results were non consistent. On the basis of general mean the WSE values were in the range of 10.28-23.72 per cent

**Table-4(b) Relative lateral dry root yield of Gambhari/Shivan (*Gmelina arborea*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | | | |
|---|---|---|---|---|---|---|
| | 24 | 30 | 36 | 24 | 30 | 36 |
| **Plant spacing (cm)** | Dry root yield (g plant$^{-1}$) | | | Dry root yield (q ha$^{-1}$) | | |
| S1-(100 X 150 ) | 145.19 | 327.31 | 394.75 | 9.69 | 21.84 | 26.34 |
| S2-(100 X 100 ) | 86.92 | 766.04 | 351.29 | 8.70 | 16.62 | 35.16 |
| S3-(100 X 50 ) | 39.60 | 74.73 | 103.37 | 7.93 | 14.95 | 20.69 |
| SE (m) ± | 1.91 | 8.13 | 4.48 | 0.16 | 0.60 | 0.45 |
| CD at 5%sd | 5.59 | 23.86 | 13.12 | 0.48 | 1.78 | 1.31 |
| **FYM levels (t ha$^{-1}$)** | | | | | | |
| F 1 -0.0 | 75.14 | 134.83 | 195.86 | 7.06 | 12.59 | 19.89 |
| F 2 -2.0 | 79.78 | 171.72 | 251.07 | 7.65 | 16.66 | 25.50 |
| F 3 -4.0 | 99.69 | 225.11 | 322.70 | 9.80 | 20.69 | 30.44 |
| F 4 -6.0 | 107.66 | 225.78 | 852.92 | 10.58 | 21.26 | 33.76 |
| SE (m) ± | 2.20 | 9.39 | 5.17 | 0.19 | 0.70 | 0.51 |
| CD at 5% | 6.45 | 27.56 | 15.16 | 0.56 | 2.06 | 1.51 |
| **Interaction S x F** | | | | | | |
| S1F1 | 120.50 | 226.25 | 256.75 | 8.04 | 15.10 | 17.13 |
| S1F2 | 125.50 | 273.50 | 356.00 | 8.37 | 18.25 | 23.75 |
| S1F3 | 160.00 | 419.50 | 477.50 | 10.68 | 27.99 | 31.86 |
| S1F4 | 174.75 | 390.00 | 488.75 | 11.66 | 26.02 | 32.61 |
| S2F1 | 78.67 | 129.83 | 236.67 | 7.87 | 12.99 | 23.69 |
| S2F2 | 82.17 | 166.17 | 327.50 | 8.22 | 16.63 | 32.78 |
| S2F3 | 91.00 | 171.00 | 387.00 | 9.11 | 17.11 | 38.73 |
| S2F4 | 95.83 | 197.17 | 454.00 | 9.59 | 19.73 | 45.44 |
| S3F1 | 26.25 | 48.40 | 94.17 | 5.25 | 9.69 | 18.84 |
| S3F2 | 31.67 | 75.50 | 99.73 | 6.34 | 15.11 | 19.96 |
| S3F3 | 48.08 | 84.83 | 103.60 | 9.62 | 16.98 | 20.74 |
| S3F4 | 52.40 | 90.17 | 116.00 | 10.49 | 18.05 | 23.22 |
| SE (m) ± | 3.81 | 16.27 | 8.95 | 0.33 | 1.21 | 0.51 |
| CD at 5% | 11.18 | 47.73 | 26.26 | 0.96 | 1.72 | 2.61 |

in the roots harvested from 6th months onwards up to 36th months at an interval of 6 months growth period. Further, it was observed that the WSE values (23.72%) was highest in the roots harvested at 6th months (i.e. December 2008) followed by WSE (21.39 %) recorded at 24th months (i.e. June 2010) and WSE (20.36%) observed at 18th months (i.e.December, 2009).Comparatively lowest WSE values were noticed in the roots harvested at 30th months (December 2010), followed by 36th months (June, 2011) and 12th months (June, 2009).

The data on alcohol soluble extractive values revealed that the various plant spacing and the manurial treatments i.e. application of different levels of Farm Yard Manure did not influenced the ASE values in the roots of Gambhari. On the basis of general mean the ASE values were in the range of 7.55-13.12 per cent in the roots harvested from 6th months onwards up to 36th months at an interval of 6 months growth period. Further, it was observed that the ASE values (13.12 %) was highest in the roots harvested at 24th months (i.e. June 2010) followed by ASE (10.64%) recorded at 18th months (i.e.December, 2009) and ASE (10.20per cent) observed at 12th months (i.e.June, 2009). Comparatively lowest ASE values (7.55%) were noticed in the roots harvested at 30th months (December 2010), followed by 6th months (December, 2008) and 36th months (June, 2011). On the basis of general mean the total ash values were in the range of 2.31-6.79 per cent and acid insoluble ash values were in the range of 0.79-4.21 per cent in the roots harvested from 6th months onwards up to 36th months (Table 6).

As the results obtained on physico-chemical constituents were not consistent with the manurial treatments i.e. application of different levels of FYM, the composite samples for each plant spacing (i.e.S1,S2 and S3) with FYM @ 2 t FYM **ha$^{-1}$** were analysed for phyto-chemical constituents. The results obtained are presented in Table-7.

The total flavonoids values were in the range of 2.00-6.46 per cent, Alkaloid values were in the range of 0.33-2.35 per cent, Phenols values were in the range of 0.77-1.19 per cent and Glycosides values were in the range of 1.29-5.88 per cent in the roots harvested from 6th months onwards up to 36th months at an interval of 6 months growth period. Further, it is observed that the values of these phyto-chemical constituents were maximum in the roots harvested at 24th months onwards. The WSE values observed in the roots of Gambhari, harvested at 18-24th months under the study conforms the accepted limits and is having higher relevance in context of Ayurvedic methods of drug usage as these values are indicative of phyto-constituents in a given quantity medicinal plant material (Padma, *et.al* 2010).

Further, it is observed that the values of these phyto-chemical constituents were maximum in the roots of the brihat-panchmoola species under study harvested at 18th-24th months onwards. Phyto-chemicals, polyphenols are largely recognized as anti-inflammatory, antiviral, antimicrobial and antioxidant agent (Narayana, *et.al.2001*). As such, phenolics and flavanoides constitute major group of compounds which act as primary antioxidants (Adesegun *et.al.* 2009) are known to react with hydroxyl radicals (Hussain *et.al.*1987) super-oxide anion radicals (Afanaslev *et.al.* 1989), lipid peroxiradicals (Torel *et.al.*1986), protect DNA from oxidative damage inhibitory against tumor cells and possess anti-inflammatory and antimicrobial properties. Thus, the results of this study signify that the roots of Gambhari/ Shivan(*Gmelina arborea*) of the age of 18-24 months growth period could be a source of natural antioxidant and anti-inflammatory drug.

## CONCLUSION

Considering various aspects such as dry root yield, per cent WSE, total alkaloids, total flavonoids, total glycosides standards provided by Ayurvedic Pharmacopoeia of India and the most importantly the feasibility and cost effectiveness of root harvesting, it can be concluded that the roots of *Gmelina arborea* (Gambhari/Shivan) can be harvested at the age of 24 months . The plant spacing of 100 x 100-150 cm with FYM application @ 2 t ha$^{-1}$. found superior among all the treatments under study.

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**Table 5 : Water and Alcohol Soluble Extractive values of Gambhari/Shivan (*Gmelina arborea*) roots as influenced by plant spacing and FYM levels.**

| Treatment combinations | Growth Period (Months) | | | | | |
|---|---|---|---|---|---|---|
| | 6 | 12 | 18 | 24 | 30 | 36 |
| **Plant spacing x FYM levels** | **Water Soluble Extractive (%)** | | | | | |
| **S 1 100 x 150 cm** | | | | | | |
| F 1 0.0 t FYM $ha^{-1}$ | 27.83 | 12.36 | 21.89 | 23.64 | 11.80 | 12.97 |
| F 2 2.0 t FYM $ha^{-1}$ | 26.72 | 14.90 | 22.81 | 22.78 | 10.20 | 12.87 |
| F 3 4.0 t FYM $ha^{-1}$ | 29.47 | 14.51 | 21.18 | 22.44 | 11.30 | 11.43 |
| F 4 6.0 t FYM $ha^{-1}$ | 29.53 | 15.11 | 20.76 | 24.68 | 8.80 | 10.61 |
| Mean | 28.39 | 14.22 | 21.66 | 23.39 | 10.53 | 11.97 |
| **S 2 100 x 100 cm** | | | | | | |
| F 1 0.0 t FYM $ha^{-1}$ | 28.45 | 15.23 | 21.33 | 24.06 | 9.06 | 14.05 |
| F 2 2.0 t FYM $ha^{-1}$ | 28.12 | 12.63 | 16.31 | — | 12.60 | 12.67 |
| F 3 4.0 t FYM $ha^{-1}$ | 18.10 | 14.01 | 19.96 | 19.72 | 6.38 | 12.33 |
| F 4 6.0 t FYM $ha^{-1}$ | 21.08 | 13.46 | 19.37 | 20.16 | 12.25 | 13.53 |
| Mean | 23.94 | 13.83 | 19.24 | 21.31 | 10.07 | 13.15 |
| **S 3 100 x 50 cm** | | | | | | |
| F 1 0.0 t FYM $ha^{-1}$ | 19.20 | 13.66 | 19.10 | 17.78 | 12.32 | 12.49 |
| F 2 2.0 t FYM $ha^{-1}$ | 18.24 | 15.68 | 19.58 | 18.24 | 9.75 | 13.66 |
| F 3 4.0 t FYM $ha^{-1}$ | 18.41 | 15.93 | 20.63 | 19.82 | 8.86 | 11.08 |
| F 4 6.0 t FYM $ha^{-1}$ | 19.47 | 19.85 | 21.39 | 22.08 | 10.04 | 10.77 |
| Mean | 18.83 | 16.28 | 20.18 | 19.48 | 10.24 | 12.00 |
| General Mean | 23.72 | 14.78 | 20.36 | 21.39 | 10.28 | 12.37 |
| **Plant spacing x FYM levels** | **Alcohol Soluble Extractive (%)** | | | | | |
| **S 1 100 x 150 cm** | | | | | | |
| F 1 0.0 t FYM $ha^{-1}$ | 8.92 | 8.72 | 11.87 | 11.36 | 8.65 | 9.18 |
| F 2 2.0 t FYM $ha^{-1}$ | 7.55 | 7.44 | 12.37 | 12.48 | 7.16 | 10.00 |
| F 3 4.0 t FYM $ha^{-1}$ | 7.88 | 9.41 | 12.63 | 13.72 | 7.16 | 8.67 |
| F 4 6.0 t FYM $ha^{-1}$ | 8.44 | 11.03 | 11.41 | 13.46 | 7.88 | 9.62 |
| Mean | 8.20 | 9.15 | 12.07 | 12.76 | 7.71 | 9.37 |
| **S 2 100 x 100 cm** | | | | | | |
| F 1 0.0 t FYM $ha^{-1}$ | 7.30 | 11.63 | 12.66 | 14.14 | 6.23 | 10.59 |
| F 2 2.0 t FYM $ha^{-1}$ | 7.97 | 10.41 | 8.90 | — | 8.34 | 11.42 |
| F 3 4.0 t FYM $ha^{-1}$ | 8.24 | 9.85 | 10.78 | 13.82 | 8.82 | 9.67 |
| F 4 6.0 t FYM $ha^{-1}$ | 8.75 | 10.12 | 9.47 | 14.44 | 7.99 | 10.55 |
| Mean | 8.06 | 10.50 | 10.45 | 14.13 | 7.85 | 10.56 |
| **S 3 100 x 50 cm** | | | | | | |
| F 1 0.0 t FYM $ha^{-1}$ | 8.77 | 9.61 | 9.07 | 10.76 | 7.18 | 11.00 |
| F 2 2.0 t FYM $ha^{-1}$ | 9.42 | 11.35 | 9.23 | 12.60 | 7.20 | 9.23 |
| F 3 4.0 t FYM $ha^{-1}$ | 9.27 | 10.74 | 9.15 | 13.52 | 7.01 | 10.84 |
| F 4 6.0 t FYM $ha^{-1}$ | 8.34 | 12.15 | 10.23 | 13.00 | 7.00 | 10.20 |
| Mean | 8.95 | 10.96 | 9.42 | 12.47 | 7.10 | 10.32 |
| General Mean | 8.40 | 10.20 | 10.64 | 13.12 | 7.55 | 10.08 |

**Table-6 Total ash and Acid insoluble ash of Gambhar/Shivan (*Gmelina arborea*) roots as influenced by plant spacing and FYM levels**

| Treatment combinations | Growth Period (Months) | | | | | |
|---|---|---|---|---|---|---|
| | **6** | **12** | **18** | **24** | **30** | **36** |
| **Plant spacing x FYM levels** | | | **Total ash (%)** | | | |
| **S 1 100 x 150 cm** | | | | | | |
| F 1 0.0 t FYM $ha^{-1}$ | 7.11 | 3.82 | 2.36 | 3.47 | 4.59 | 6.27 |
| F 2 2.0 t FYM $ha^{-1}$ | 5.95 | 4.80 | 2.56 | 3.46 | 3.65 | 4.94 |
| F 3 4.0 t FYM $ha^{-1}$ | 7.29 | 2.83 | 2.41 | 5.41 | 3.81 | 5.22 |
| F 4 6.0 t FYM $ha^{-1}$ | 6.18 | 3.36 | 2.68 | 5.07 | 4.46 | 6.08 |
| **Mean** | **6.63** | **3.70** | **2.50** | **4.35** | **4.13** | **5.63** |
| **S 2 100 x 100 cm** | | | | | | |
| F 1 0.0 t FYM $ha^{-1}$ | 6.01 | 3.62 | 2.41 | 12.58 | 4.43 | 4.36 |
| F 2 2.0 t FYM $ha^{-1}$ | 7.95 | 3.84 | 1.85 | — | 4.95 | 7.38 |
| F 3 4.0 t FYM $ha^{-1}$ | 7.01 | 4.51 | 2.22 | 4.51 | 6.03 | 7.69 |
| F 4 6.0 t FYM $ha^{-1}$ | 5.35 | 3.35 | 2.44 | 3.84 | 5.85 | 6.47 |
| **Mean** | **6.58** | **3.83** | **2.23** | **6.98** | **5.32** | **6.48** |
| **S 3 100 x 50 cm** | | | | | | |
| F 1 0.0 t FYM $ha^{-1}$ | 6.25 | 3.60 | 2.05 | 5.25 | 6.30 | 4.90 |
| F 2 2.0 t FYM $ha^{-1}$ | 12.27 | 5.12 | 1.91 | 4.99 | 4.03 | 4.80 |
| F 3 4.0 t FYM $ha^{-1}$ | 2.59 | 5.86 | 2.58 | 6.29 | 3.37 | 5.08 |
| F 4 6.0 t FYM $ha^{-1}$ | 7.51 | 5.23 | 2.26 | 5.55 | 5.42 | 5.29 |
| **Mean** | **7.16** | **4.95** | **2.20** | **5.52** | **4.78** | **5.02** |
| **General Mean** | **6.79** | **4.16** | **2.31** | **5.61** | **4.74** | **5.71** |
| **Plant spacing x FYM levels** | | | **Acid insoluble ash (%)** | | | |
| **S 1 100 x 150 cm** | | | | | | |
| F 1 0.0 t FYM $ha^{-1}$ | 4.12 | 1.39 | 0.62 | 0.95 | 2.14 | 3.62 |
| F 2 2.0 t FYM $ha^{-1}$ | 3.56 | 2.32 | 0.80 | 1.25 | 1.40 | 3.12 |
| F 3 4.0 t FYM $ha^{-1}$ | 4.80 | 1.07 | 0.67 | 2.39 | 1.83 | 3.08 |
| F 4 6.0 t FYM $ha^{-1}$ | 3.92 | 1.63 | 0.92 | 2.10 | 2.51 | 3.89 |
| **Mean** | **4.10** | **1.60** | **0.75** | **1.67** | **1.97** | **3.43** |
| **S 2 100 x 100 cm** | | | | | | |
| F 1 0.0 t FYM $ha^{-1}$ | 3.15 | 1.52 | 0.71 | 9.70 | 1.60 | 2.85 |
| F 2 2.0 t FYM $ha^{-1}$ | 4.70 | 1.93 | 0.91 | — | 2.57 | 4.81 |
| F 3 4.0 t FYM $ha^{-1}$ | 4.72 | 2.24 | 0.86 | 1.92 | 2.84 | 4.51 |
| F 4 6.0 t FYM $ha^{-1}$ | 3.58 | 1.43 | 0.82 | 1.85 | 3.74 | 4.05 |
| **Mean** | **4.04** | **1.78** | **0.83** | **4.49** | **2.69** | **4.06** |
| **S 3 100 x 50 cm** | | | | | | |
| F 1 0.0 t FYM $ha^{-1}$ | 3.78 | 1.65 | 0.65 | 2.35 | 2.60 | 2.60 |
| F 2 2.0 t FYM $ha^{-1}$ | 8.48 | 2.56 | 0.69 | 0.83 | 1.43 | 2.94 |
| F 3 4.0 t FYM $ha^{-1}$ | 1.18 | 2.77 | 0.88 | 2.33 | 2.74 | 2.73 |
| F 4 6.0 t FYM $ha^{-1}$ | 4.60 | 2.25 | 0.95 | 2.69 | 1.79 | 2.97 |
| **Mean** | **4.51** | **2.31** | **0.79** | **2.05** | **2.14** | **2.81** |
| **General Mean** | **4.21** | **1.89** | **0.79** | **2.73** | **2.26** | **3.43** |

**Table 7 : Total flavonoids, Alkaloid, Phenols and Glycosides in Gambhar/Shivan (*Gmelina arborea*) roots as influenced by different plant spacing.**

| Treatment combinations | Growth Period (Months) | | | | |
|---|---|---|---|---|---|
| | 12 | 18 | 24 | 30 | 36 |
| **Plant spacing x FYM levels** | **Total Flavonoids (%)** | | | | |
| **S 1 100 x 150 cm x**F 2 2.0 t FYM ha$^{-1}$ | **1.50** | 1.70 | 4.77 | 4.00 | 3.06 |
| **S 2 100 x 100 cm x**F 2 2.0 t FYM ha$^{-1}$ | – | 2.70 | 6.27 | 3.34 | 4.34 |
| **S 3 100 x 50 cm x**F 2 2.0 t FYM ha$^{-1}$ | 2.50 | 1.80 | **8.34** | 3.90 | 3.62 |
| **Mean** | **2.00** | **2.07** | **6.46** | **3.75** | **3.67** |
| | **Alkaloid (%)** | | | | |
| **S 1 100 x 150 cm x**F 2 2.0 t FYM ha$^{-1}$ | 0.68 | 0.24 | **1.39** | 2.13 | 2.07 |
| **S 2 100 x 100 cm x**F 2 2.0 t FYM ha$^{-1}$ | – | 0.44 | 0.38 | 2.14 | 2.16 |
| **S 3 100 x 50 cm x**F 2 2.0 t FYM ha$^{-1}$ | 0.17 | 0.31 | 0.70 | 2.07 | 2.83 |
| **Mean** | **0.43** | **0.33** | **0.82** | **2.11** | **2.35** |
| | **Phenols (%)** | | | | |
| **S 1 100 x 150 cm x**F 2 2.0 t FYM ha$^{-1}$ | 0.90 | 0.75 | **1.11** | 0.87 | 1.18 |
| **S 2 100 x 100 cm x**F 2 2.0 t FYM ha$^{-1}$ | – | 0.85 | 1.02 | 0.95 | 1.20 |
| **S 3 100 x 50 cm x**F 2 2.0 t FYM ha$^{-1}$ | 1.10 | **0.70** | 0.90 | 0.95 | 1.18 |
| **Mean** | **1.00** | **0.77** | **1.01** | **0.92** | **1.19** |
| | **Glycosides (%)** | | | | |
| **S 1 100 x 150 cm x**F 2 2.0 t FYM ha$^{-1}$ | 3.30 | 5.48 | 6.16 | 4.30 | 1.13 |
| **S 2 100 x 100 cm x**F 2 2.0 t FYM ha$^{-1}$ | – | 4.40 | **7.15** | **5.08** | 1.09 |
| **S 3 100 x 50 cm x**F 2 2.0 t FYM ha$^{-1}$ | 4.20 | 4.10 | 4.32 | 4.60 | 1.65 |
| **Mean** | **3.75** | **4.66** | **5.88** | **4.66** | **1.29** |

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# Influence of Plant Growth Regulators on Seed Yield and Economics of Fenugreek (*Trigonella foenum-graecum* L.)

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## ABSTRACT

The present investigation was carried out during *Rabi* season of 2018-2019 at Instructional farm Department of Vegetable Science, Dr. Panjabrao Krishi Vidyapeeth, Akola. The experiment was laid out in Randomized Block Design with three replications. The treatment consisted of two concentrations of each plant growth regulator namely $GA_3$ 75 ppm, $GA_3$ 100 ppm, NAA 25 ppm, NAA 50 ppm, Cycocel 200 ppm, Cycocel 250 ppm, Paclobutrazol 20 ppm, Paclobutrazol 30 ppm and Control (water spraying). The experiment was thus conducted with nine treatments. Among the PGRs,an application of NAA 25 ppm recorded maximum number of pod plant$^{-1}$, number of seed pod$^{-1}$, seed yield plant$^{-1}$, seed yield plot$^{-1}$, seed yield ha$^{-1}$, test weight and B:C ratio.

Fenugreek (*Trigonella foenum-graecum* L.) is an important condiment occupying third place in area and fourth in production among all the minor spices grown in our country. It is a small seed with yellowish brown colour. It is a rich source of proteins, minerals, vitamin-A and C (Das,1992). Fenugreek belongs to family Leguminosae, subfamily Papilionaceae and genus *Trigonella*. It is an annual crop. The nodules founds at the tip of side roots have nitrogen fixing bacteria which fix nitrogen in the soil and thus add to the fertility of the soil.

Growth regulators are organic compounds other than nutrients, small amount of which are capable of modifying growth (Lepold, 1963). Among the growth regulators, auxin causes enlargement of plant cell and gibberellins stimulate cell division, cell enlargement or both (Nickell, 1982). Gibberellic acid ($GA_3$) may be a contributor in achieving the desired goal. Plant growth regulators have great potential in increasing agricultural production and helps in removing many of the barriers imposed by genetics and environment. Exogenous application of PGR's has been reported to improve the growth and yield of various crops (Bharud *et al*. 1988). It is well known that all the PGRs regulate the physiological functions or processes of plant.

Though the plant growth regulators are useful and also available in the market but their use and concentrations have not been standardized in fenugreek. In India several research workers have studied the effect of plant growth regulators on various vegetable crops, especially on seed treatments, seedling treatments and foliar application. However, scanty information is available on the effect of foliar application of plant growth regulators in fenugreek seed production.

Plant growth regulators have been tried to improve the growth and ultimately yield. Among the growth regulators Cultar, CCC, NAA and $GA_3$ exhibits beneficial effect in several crops. However, information on effect of Cultar, CCC, NAA and $GA_3$ on fenugreek seed production under Vidarbha condition is not available. Therefore, the present investigation was undertakento study the effect of Cultar,CCC, NAA and $GA_3$ on seed yield and economics of fenugreek.

## MATERIAL AND METHODS

A field experiment was conducted during the *Rabi* season of 2018-2019 at Instructional farm Department of Vegetable Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The experiment was laid out in Randomized Block Design with three replications. The treatment consisted of two concentrations of each plant growth regulator namely $GA_3$ 75 ppm, $GA_3$ 100 ppm, NAA 25 ppm, NAA 50 ppm, Cycocel 200 ppm, Cycocel 250 ppm, Paclobutrazol 20 ppm, Paclobutrazol 30 ppm, Control (water spraying). Seeds of CO-1 variety were sown in the plot of 2m x 1.5m at spacing of 30 cm x 10 cm. The crop was

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**Table 1.Effect of plant growth regulators on seed yield of fenugreek.**

| Treatments | Number of pods plant$^{-1}$ | Number of seed pod$^{-1}$ | Seed yield g plant$^{-1}$ | Seed yield plot$^{-1}$ | Seed yield q ha$^{-1}$ | Test weight (g) |
|---|---|---|---|---|---|---|
| $T_1$- $GA_3$ 75 ppm | 30.93 | 15.48 | 5.82 | 363.00 | 12.10 | 15.09 |
| $T_2$- $GA_3$ 100 ppm | 31.14 | 17.21 | 6.76 | 382.67 | 12.31 | 14.81 |
| $T_3$-NAA 25 ppm | 32.83 | 17.22 | 7.20 | 532.67 | 17.76 | 18.04 |
| $T_4$-NAA 50 ppm | 32.59 | 15.23 | 7.02 | 494.67 | 16.48 | 16.17 |
| $T_5$-Cycocel 200 ppm | 31.44 | 16.11 | 6.65 | 384.67 | 12.82 | 14.51 |
| $T_6$-Cycocel 250 ppm | 32.31 | 15.34 | 5.66 | 394.00 | 13.13 | 17.09 |
| $T_7$-Paclobutrazol 20ppm ppm | 30.00 | 14.27 | 7.04 | 369.33 | 12.76 | 15.30 |
| $T_8$-Paclobutrazol 30ppm ppm | 31.33 | 15.24 | 6.44 | 465.00 | 15.50 | 17.26 |
| $T_9$-Control | 15.07 | 13.42 | 4.65 | 281.67 | 7.22 | 13.83 |
| SE(m)± | 0.21 | 0.47 | 0.07 | 0.95 | 0.09 | 0.49 |
| CD at 5 % | 0.63 | 1.40 | 0.21 | 2.85 | 0.27 | 1.47 |

**Table 2.Effect of plant growth regulators on Economics of fenugreek**

| Treatments | Yield (q ha$^{-1}$) | Cost of Cultivation (Rs. ha$^{-1}$) | GMR (Rs. ha$^{-1}$) | NMR (Rs. ha$^{-1}$) | B:C Ratio |
|---|---|---|---|---|---|
| $T_1$- $GA_3$ 75 ppm | 12.10 | 46126 | 96800 | 50674 | 1.9 |
| $T_2$- $GA_3$ 100 ppm | 12.31 | 49489 | 98480 | 48991 | 2.4 |
| $T_3$-NAA 25 ppm | 17.76 | 39855 | 142080 | 102225 | 3.5 |
| $T_4$-NAA 50 ppm | 16.48 | 40665 | 131840 | 93175 | 3.4 |
| $T_5$-Cycocel 200 ppm | 12.82 | 57045 | 102560 | 45515 | 1.8 |
| $T_6$-Cycocel 250 ppm | 13.13 | 62045 | 105040 | 42995 | 1.7 |
| $T_7$-Paclobutrazol 20 ppm ppm | 12.76 | 62712 | 102080 | 39368 | 1.6 |
| $T_8$-Paclobutrazol 30 ppm ppm | 15.50 | 76045 | 124000 | 47955 | 1.6 |
| $T_9$-Control(water spray) | 7.22 | 39045 | 57760 | 21833 | 1.4 |
| SE(m)± | 0.09 | | | 1566.51 | 0.27 |
| CD at 5 % | 0.27 | | | 4736.82 | 0.81 |

fertilized with 12 tons of FYM ha$^{-1}$ along with NPK @ 45:40:30 Kg ha$^{-1}$ as basal dose. Another 15 kg N ha$^{-1}$ was top dressed at 60 days after sowing. Growth regulators were applied as foliar spray at 30 and 60 DAS as per the treatments and untreated control plots were sprayed with water. Need based intercultural operations were taken. Five plant samples from each replication were selected at random to record morphological, yield and quality attributing characters. The economics of treatment was calculated on the basis of prevailing market rate.

## RESULTS AND DISCUSSION

**Seed yield and yield attributing characters**

The significant differences in seed yield attributing characters like number of pod plant$^{-1}$, number of seed pod$^{-1}$, seed yield plant$^{-1}$, seed yield plot$^{-1}$ and seed yield ha$^{-1}$, test weight were recorded among different growth regulators and their different concentration. The maximum numbers of pod plant$^{-1}$ (32.83) were recorded with application of NAA 25 ppm, while minimum (15.07) was recorded in the controltreatment. The highest number of seeds pod$^{-1}$ (17.22) was observed in treatment with NAA 25 ppm, however it was lowest (13.42) under the control treatment. Similarly the maximum seed yield plant$^{-1}$ (7.20 g) was recorded under the treatment of NAA 25 ppm and it was minimum (4.65 g) in the control treatment.The highest seed yield plot$^{-1}$ (532.67 g) was recorded with the application of NAA 25 ppm, however it was minimum (281.67 kg) in the control treatment. The treatment receiving NAA 25 ppm recorded significantly highest seed yield (17.76 q ha$^{-1}$) and it was minimum (7.22 q ha$^{-1}$) under the control treatment. The test weight (18.04 g) was recorded highest in treatment wherein NAA 25 ppm was applied. However, minimum test weight was observed (13.83 g) under the control treatment.

The makeable improvement in fenugreek seed primarily appears to be a function of greater photosynthetic efficiency per unit land area, maintenance of its higher rate for longer period, especially during post-flowering period and at the late pod filling stage leads to increase greater accumulation of dry matters which resulted in higher productivity of crop. Significant improvement in yield is in accordance with the findings of Gour *et al*. (2009), Singh *et al.* (2012) and Meena *et al.*(2013) in fenugreek.

The maximum net return and B:C ratio (Rs.102225 ha$^{-1}$ and 3.5, respectively) was obtained with the application of NAA 25 ppm followed by the application of NAA 50 ppm (Rs.93175 ha$^{-1}$ and 3.4, respectively). However, the minimum net return and B:C ratio (Rs.21833 ha$^{-1}$ and 1.4) was obtained under the control treatment.

This might be due to the fact that the price of NAA was very less and the seed yield was also higher.

## CONCLUSION

From the findings of the present investigation, it can be concluded that,the application of NAA 25 ppm noted the better yield attributing characters viz. number of pod plant$^{-1}$, number of seed pod$^{-1}$, seed yield plant$^{-1}$, seed yield ha$^{-1}$ were maximum with highest B:C ratio.

The economics of plant growth regulators treatment also indicated that foliar application of NAA 25 ppm at 30 days, 45 days and 60 days after sowing was more profitable in terms of net returns and B:C ratio in comparison to rest of the treatments.

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# Short Term Root Biomass Production with Quality of *Oroxylum indicum* - a Species of Brihatpanchmool as Influenced by Plant Geometry and Organic Manure

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## ABSTRACT

To assess the growth and root yield performance of Shonak/Tetu a tree species was planted under different geometry and soil fertility during *Kharif* season 2008-09 the treatments comprising of three plant spacings 100 x 150 cm ($S_1$ 6,666 Plant population ha$^{-1}$), 100 x 100 cm ($S_2$ 10,000 Plant population ha$^{-1}$) ,100 x 50 cm ($S_3$ 20,000 Plant population ha$^{-1}$) and four levels of FYM viz.0.0(F1), 2.0(F2), 4.0(F3), 6.0(F4) t ha$^{-1}$ with the plot size of 6.0 x 6.0 m. The observations on plant height, number of branches, root length and girth , fresh and dry root yield were recorded up to 3 years at an interval of six months growth period. The plants of Shonak/Tetu (*Oroxylum indicum*), were completely uprooted at 6, 12 and 18 month's growth period for recording the root yield including tap root. The woody and hard tap root is rather less pharmaceutical important and therefore at 24, 30 and 36 months growth period only lateral roots were harvested. The physicochemical and phyto-chemical analysis of the roots harvested at 6, 12, 18, 24, 30 and 36 months growth period was carried out. After 6 months of growth period, the plant height, root length, root girth and dry root yield plant$^{-1}$ of Shonak was highest with the plant spacing of 100 x 150 cm and FYM @ 2 t ha$^{-1}$ ($S_1xF_2$). Similarly, at 12 months of growth stage, the root length, root girth and dry root yield plant$^{-1}$ and total glycosides were also highest with the plant spacing of 100 x 150 cm and FYM @ 2 t ha$^{-1}$ ($S_1$ x $F_2$). However highest flavonoid content was observed with the plant spacing of 100 x100 cm with FYM application @ 2.0 t ha$^{-1}$ ($S_2$ x $F_2$). The per cent WSE values however, were less than required (37.61 % Vs 42 %) by Ayurvedic Pharmacopoeial Standards. At the growth period of 18 months, highest no. of branches, root length, root girth dry root yield and total flavonoids and total alkaloids were observed with the plant spacing of 100 x 150 cm and FYM @ 2 t ha$^{-1}$ ($S_1$ x $F_2$). The dry root yield plant$^{-1}$ (247g) and total flavonoids contents were highest (5.3 %) with this treatment amongst all the other treatments at all the age groups tested. Flavonoids are important bioactive group in Shonak as reported in Ayurvedic Pharmacopoeia of India. The water soluble extractive (% WSE) values, though not highest, were also much above the required value (54.70 % Vs 42 %) as per the standards given in Ayurvedic Pharmacopoeia of India. At 24 months stage, the trend was random and different parameters showed highest values with different treatments. The dry root yield was highest with 100 x100 cm plant spacing with FYM application @ 2t ha$^{-1}$. Total flavonoids were highest with 100 x 150 cm plant spacing with FYM application @ 2t ha$^{-1}$. At 30 months age, the values of most of the parameters such as root length, dry root yield, per cent WSE, total flavonoids and total alkaloids were highest with the plant spacing of 100 x 150 cm and FYM application @ 2 t h$^{-1}$ ($S_1xF_2$) . The values of total flavonoids, however were much less than at 18 month age with $S_1xF_2$ treatment (5.3 % Vs 1.33 %).

The supply of the raw material particularly to that of root based material from trees of dashmool group is very meagre and hardly there are reliable data available which support supply scenario. This kind of short supply may lead to the use of either substitutes or in a very low quantity in the ayurvedic formulations and ultimately affect the efficacy of the formulations.

In view of above, it is imperative to develop the agrotechnologies of these species. and there is an urgent need for an intervention to develop and conserve the resource base for dashmool. Therefore, the present investigation was carried out with the objectives to develop the agronomic protocols for high density, short term plantation for Shonak/Tetu (*Oroxylum indicum*) a species of Brihatpanchmool and to study the yielding potential as influenced by age of the plant and time of harvesting.

Dashmoola is a fixed dose combination of 10 roots obtained from five tree species Shonak/Tetu (*Oroxylum indicum*) is one of them, two shrub / under shrub species and three herb species. These species belong to six different families of Angiosperms:

1-Professor & Principal Investigator,2-Assitt.Professor & Co- Principal Investigator, 3 & 4 Sr. Res. Fellows and 5. Associate Professor, AICRP on Medicinal, Aromatic Plants & Betelvine, Dr PDKV, Akola

Verbenaceae (2 species), Fabaceae (2 species), Solanaceae (2 species), Bignoniaceae (2 species), Rutaceae (1 species) and Zygophyllaceae (1 species).

Dashmoola is indicated for aggravations of the nervous system and pain when there are signs of debility. It is used as a decoction or enema for lower back pain, sciatica, tremors, Parkinson's disease and inflammation in the pelvic and sacral region. For dry cough and respiratory weakness when there is high *vata* Dashmoolarisht can be used as a tonic to strengthen the system. When the immune system is depleted and is not throwing off fevers the decoction can cause diaphoresis and release the trapped *ama* toxins. It is also good for influenza, colds, neuralgia, and headaches.

## MATERIAL AND METHODS

To assess the growth and root yield performance of Shonak/Tetu a tree species was planted under different geometry and soil fertility during *Kharif* season 2008-09. The treatments were comprising of three plant spacings 100 x 150 cm (S1-6,666 Plant population $ha^{-1}$),100 x 100 cm (S2-10,000 Plant population $ha^{-1}$) ,100 x 50 cm (S3-20,000 Plant population $ha^{-1}$) and four levels viz.0.0 ,2.0 ,4.0 ,6.0 t $ha^{-1}$.with the plot size of 6.0 x 6 .0 m. The observations on plant height, number of branches, root length and girth, fresh and dry root yield were recorded up to 3 years at an interval of six months growth period. The plants of Shonak/ Tetu (*Oroxylum indicum*) were completely uprooted at 6, 12 and 18 month's growth period for recording the root yield including tap root. The woody and hard tap root is rather less pharmaceutical important and therefore at 24, 30 and 36 months growth period only lateral roots were harvested. The physicochemical and phyto-chemical analysis of the roots harvested at 6, 12, 18, 24, 30 and 36 months growth period was carried out by standard methods (Torel, *et al*,1986; Agrawal and Paridhavi,2007 and Padma,*et al*.,2010 ).

## RESULTS AND DISCUSSION

### Plant height

The data presented in Table-1 revealed that the plant height was successively found to increase with each growth period. Further, it was noticed that significantly maximum plant height was recorded with the closer plant spacing 100 x 50 cm except the plant height recorded at 6 and 36 months was highest with the plant spacing of 100 x 150 cm.

Application of FYM at various levels significantly influenced the plant height and significantly maximum plant height was noticed with the application 6 t FYM per hectare at all the growth period under study. The interaction effect was found to be significant at all the growth periods. The plant spacing of 100 x 50 cm with the application of 6 t FYM per hectare (S3xF4) recorded significantly maximum plant height at 12, 18 and 30 months growth periods. The plant height noticed significantly highest at 6 and 36 months growth periods under the plant spacing 100 x 150 cm with 6 t FYM per hectare (S1xF4) and under plant spacing of 100 x 100 cm with 6t FYM (S2xF4).

### No. of branches

There was no branching to the Tetu (*Oroxylum indicum*) up to 6 months growth period. The data presented in Table-2 revealed that the number of branches was also successively found to increase with each growth period. Further, it was noticed that significantly maximum number of branches were recorded with the wider plant spacing 100 x 150 cm except the branches recorded at 12 and 36 months growth period were maximum with the plant spacing of 100 x 100 cm.

Application of FYM at various levels significantly influenced the number of branches per plant and significantly maximum branches were noticed with the application 6 t FYM per hectare at 12 and 18 months growth period. Although the number of branches per plant was significantly highest with 2 and 4 t FYM at 24-30 months growth period, however it was at par with 6t FYM per hectare. The interaction effect was found to be significant at all the growth periods. The plant spacing of 100 x 100 cm with the application of 6 t FYM per hectare (S2xF4) recorded significantly maximum branches per plant at 12, 18 and 36 months growth period. However, number of branches was noticed significantly highest at 24 and 30 months growth periods under the plant spacing 100 x 150 cm with 4 t and 2 t FYM per hectare (S1xF3, S1xF2), respectively.

### Root length and girth

The data presented in Table-3(a) revealed that the root length and girth of completely uprooted plants of

**Table 1 : Relative plant height of Shonak/Tetu (*Oroxylum indicum*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | | | |
|---|---|---|---|---|---|---|
| | 6 | 12 | 18 | 24 | 30 | 36 |
| **Plant spacing (cm)** | **Plant Height (cm)** | | | | | |
| S1-(100 X 150 ) | 29.18 | 77.25 | 89.92 | 171.08 | 230.70 | 341.56 |
| S2-(100 X 100 ) | 24.79 | 82.99 | 94.28 | 217.61 | 236.00 | 329.04 |
| S3-(100 X 50 ) | 17.29 | 86.17 | 95.42 | 232.63 | 248.75 | 317.50 |
| SE (m) ± | 0.81 | 0.65 | 1.67 | 3.08 | 3.24 | 5.41 |
| CD at 5% | 2.37 | 1.91 | 4.88 | 9.05 | 9.51 | 15.88 |
| **FYM levels (t ha$^{-1}$)** | | | | | | |
| F 1 -0.0 | 20.58 | 76.67 | 85.90 | 171.67 | 223.10 | 308.58 |
| F 2 -2.0 | 23.33 | 79.61 | 94.00 | 188.94 | 237.17 | 321.11 |
| F 3 -4.0 | 25.21 | 84.42 | 96.00 | 245.97 | 243.33 | 335.55 |
| F 4 -6.0 | 25.89 | 87.86 | 96.92 | 226.83 | 250.33 | 352.22 |
| SE (m) ± | 0.93 | 0.75 | 1.92 | 3.56 | 3.74 | 6.25 |
| CD at 5% | 2.74 | 2.21 | 5.63 | 10.44 | 10.98 | 18.34 |
| **Interaction S x F** | | | | | | |
| S1F1 | 25.25 | 72.50 | 80.50 | 118.33 | 203.30 | 318.75 |
| S1F2 | 27.83 | 75.50 | 92.00 | 160.99 | 237.50 | 328.33 |
| S1F3 | 31.63 | 78.25 | 93.67 | 215.00 | 240.00 | 347.50 |
| S1F4 | 32.00 | 82.75 | 93.50 | 190.00 | 242.00 | 371.67 |
| S2F1 | 20.50 | 75.83 | 88.20 | 152.50 | 215.00 | 307.00 |
| S2F2 | 25.17 | 80.33 | 94.00 | 171.67 | 234.00 | 325.00 |
| S2F3 | 26.33 | 86.33 | 96.67 | 268.75 | 242.00 | 336.67 |
| S2F4 | 27.17 | 89.50 | 98.25 | 277.50 | 253.00 | 347.50 |
| S3F1 | 16.00 | 81.67 | 89.00 | 244.17 | 251.00 | 300.00 |
| S3F2 | 17.00 | 83.00 | 96.00 | 219.16 | 240.00 | 310.00 |
| S3F3 | 17.67 | 88.67 | 97.67 | 254.17 | 248.00 | 322.50 |
| S3F4 | 18.50 | 91.33 | 99.00 | 213.00 | 256.00 | 337.50 |
| SE (m) ± | 1.62 | 1.31 | 3.33 | 6.17 | 6.64 | 10.82 |
| CD at 5% | 4.74 | 3.83 | 9.77 | 10.09 | 19.03 | 31.77 |

Tetu at 6, 12 and 18 months growth periods were successively found to increase with each growth period. Further, it was noticed that significantly maximum root length and girth was recorded with the wider plant spacing 100 x 150 cm.

Application of FYM at various levels significantly influenced the root length and girth and significantly maximum root length and root girth was noticed with the application 6 t FYM per hectare at all the growth period under study, except the root girth recorded at 6 months growth period. The root girth was maximum with 4 t FYM, however, it was at par with 6 t FYM per hectare. The interaction effect was found to be significant at all the growth periods. The plant spacing of 100 x 150 cm with the application of 6 t FYM per hectare (S1xF4) recorded significantly maximum root length and girth at all the growth period except the root girth recorded at 6 months growth period. The root girth noticed at 6 months growth period under the plant spacing 100 x 150 cm with 4 t FYM per hectare (S1xF3) was significantly highest, however at par under plant spacing of 100 x 150 cm with the application of 6 t FYM per hectare (S1xF4).

During the growth periods of 24, 30 and 36 months only lateral roots were harvested and the data on the lateral root length and girth is presented in Table-3(b). The lateral root length and girth was also successively found to increase with each growth period. Further, it was noticed that significantly maximum root length and girth was recorded with the wider plant spacing 100 x 150 cm.

Application of FYM at various levels

**Table 2 : Relative number of branches of Shonak/Tetu (*Oroxylum indicum*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | | | |
|---|---|---|---|---|---|---|
| | 6 | 12 | 18 | 24 | 30 | 36 |
| **Plant spacing (cm)** | | | **No.of branches** | | | |
| S1-(100 X 150 ) | — | 7.87 | 8.23 | 9.48 | 3.93 | 6.06 |
| S2-(100 X 100 ) | — | 8.04 | 8.06 | 9.01 | 3.86 | 7.01 |
| S3-(100 X 50 ) | — | 7.00 | 7.16 | 8.72 | 3.50 | 5.99 |
| SE (m)± | | 0.16 | 0.28 | 0.09 | 0.18 | 0.25 |
| CD at 5% | | 0.46 | 0.83 | 0.27 | 0.54 | 0.73 |
| **FYM levels (t ha$^{-1}$)** | | | | | | |
| F 1 -0.0 | — | 6.36 | 6.71 | 7.96 | 3.50 | 5.37 |
| F 2 -2.0 | — | 7.67 | 7.78 | 9.45 | **4.11** | 6.43 |
| F 3 -4.0 | — | 8.22 | 8.28 | 9.47 | 3.61 | 6.87 |
| F 4 -6.0 | — | 8.31 | 8.50 | 9.40 | 3.85 | 6.00 |
| SE (m)± | | 0.18 | 0.32 | 0.11 | 0.21 | 0.29 |
| CD at 5% | | 0.53 | 0.95 | 0.32 | 0.62 | 0.84 |
| **Interaction S x F** | | | | | | |
| S1F1 | — | 6.25 | 7.00 | 7.67 | 3.50 | 5.50 |
| S1F2 | — | 8.50 | 8.50 | 9.75 | 4.50 | 6.00 |
| S1F3 | — | 8.50 | 8.67 | 10.50 | 4.00 | 6.75 |
| S1F4 | — | 8.25 | 8.75 | 10.00 | 3.75 | 6.00 |
| S2F1 | — | 6.83 | 6.80 | 8.00 | 3.67 | 6.60 |
| S2F2 | — | 8.17 | 8.17 | 9.60 | 4.17 | 7.00 |
| S2F3 | — | 8.50 | 8.50 | 9.25 | 3.83 | 7.20 |
| S2F4 | — | 8.67 | 8.75 | 9.20 | 3.80 | 7.25 |
| S3F1 | — | 6.00 | 6.33 | 8.20 | 3.33 | 4.00 |
| S3F2 | — | 6.33 | 6.67 | 9.00 | 3.67 | 6.30 |
| S3F3 | — | 7.67 | 7.67 | 8.67 | 3.00 | 6.67 |
| S3F4 | — | 8.00 | 8.00 | 9.00 | 4.00 | 7.00 |
| SE (m)± | | 0.31 | 0.56 | 0.19 | 0.37 | 0.50 |
| CD at 5% | | 0.92 | 1.65 | 0.55 | 1.07 | 1.46 |

significantly influenced the root length and girth and significantly maximum root length and root girth was noticed with the application 6 t FYM per hectare at all the growth periods (24, 30 and 36 months) under study.The interaction effect was found to be significant at all the growth periods. The plant spacing of 100 x 150 cm with the application of 6 t FYM per hectare (S1xF4) recorded significantly maximum root length and significantly highest root girth under plant spacing of 100 x 100 cm and 4 t FYM per hectare (S2xF3) at all the growth periods.

**Root yield**

The data presented in Table 4 (a) revealed that the dry root yield of completely uprooted plants of Tetu at 6, 12 and 18 months growth periods was found to increase markedly with each growth period. The root yield was in the range of 0.33-1.30 q $ha^{-1}$ at 6 months, 2.53-8.07 q $ha^{-1}$ at 12 months and 14.87-40.03 q $ha^{-1}$ at 18 months growth period. Further, it was noticed that significantly highest root yield at 6, 12 and 18 months growth periods was recorded with the closer plant spacing 100 x 50 cm

**Table-3(a) Relative root length and girth of completely uprooted plants of Shonak/Tetu (*Oroxylum indicum*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | | | |
|---|---|---|---|---|---|---|
| | 6 | 12 | 18 | 6 | 12 | 18 |
| **Plant spacing (cm)** | | **Root length (cm)** | | | **Root girth (cm)** | |
| S1-(100 X 150 ) | 19.02 | 32.75 | 34.25 | 1.42 | 2.97 | 3.79 |
| S2-(100 X 100 ) | 17.69 | 32.00 | 34.09 | 1.25 | 2.86 | 3.77 |
| S3-(100 X 50 ) | 16.54 | 30.83 | 32.21 | 1.05 | 2.08 | 3.61 |
| SE (m) ± | 0.38 | 0.54 | 0.68 | 0.02 | 0.04 | 0.03 |
| CD at 5% | 1.25 | 1.57 | 1.99 | 0.07 | 0.11 | 0.10 |
| **FYM levels (t $ha^{-1}$)** | | | | | | |
| F 1 -0.0 | 16.83 | 29.47 | 29.84 | 1.09 | 2.33 | 3.57 |
| F 2 -2.0 | 17.05 | 31.50 | 33.67 | 1.20 | 2.57 | 3.71 |
| F 3 -4.0 | 18.28 | 32.05 | 35.22 | 1.36 | 2.74 | 3.78 |
| F 4 -6.0 | 18.83 | 34.42 | 35.33 | 1.31 | 2.91 | 3.84 |
| SE (m) ± | 0.44 | 0.62 | 0.78 | 0.03 | 0.04 | 0.04 |
| CD at 5% | 1.30 | 1.82 | 2.30 | 0.08 | 0.13 | 0.12 |
| **Interaction S x F** | | | | | | |
| S1F1 | 17.75 | 30.75 | 30.00 | 1.28 | 2.63 | 3.6 |
| S1F2 | 18.33 | 32.00 | 34.50 | 1.38 | 2.87 | 3.78 |
| S1F3 | 20.00 | 32.50 | 36.00 | 1.53 | 3.10 | 3.87 |
| S1F4 | 20.00 | 35.75 | 36.50 | 1.48 | 3.28 | 3.93 |
| S2F1 | 17.08 | 29.00 | 30.20 | 1.07 | 2.43 | 3.62 |
| S2F2 | 17.50 | 31.50 | 34.17 | 1.22 | 2.80 | 3.78 |
| S2F3 | 18.17 | 32.33 | 36.00 | 1.42 | 3.00 | 3.83 |
| S2F4 | 18.00 | 35.17 | 36.00 | 1.30 | 3.22 | 3.85 |
| S3F1 | 15.67 | 28.67 | 29.33 | 0.93 | 1.93 | 3.50 |
| S3F2 | 15.38 | 31.00 | 32.33 | 1.00 | 2.03 | 3.57 |
| S3F3 | 16.67 | 31.33 | 33.67 | 1.13 | 2.13 | 3.63 |
| S3F4 | 18.50 | 32.33 | 33.50 | 1.15 | 2.23 | 3.75 |
| SE (m) ± | 0.77 | 1.07 | 1.36 | 0.05 | 0.05 | 0.07 |
| CD at 5% | 2.25 | 3.14 | 3.99 | 0.14 | 0.22 | 0.20 |

Application of FYM at various levels significantly influenced the dry root yield and significantly maximum root yield was noticed with the application 6 t FYM per hectare, at all the growth period, however it was at par with the application 4 t FYM per hectare at 18 months growth period under study.The interaction effect was found to be significant at all the growth periods. The plant spacing of 100 x 50 cm with the application of 6 t FYM per hectare (S3xF4) recorded significantly maximum dry root yield at all the growth period(6, 12 and 18 months).

During the growth periods of 24, 30 and 36 months only lateral roots were harvested and the data generated on the lateral root yield is presented in Table4(b). The lateral root yield was also successively found to increase with each growth period. The root yield was in the range of 7.67-29.86 q $ha^{-1}$ at 24 months, 8.82-33.10 q $ha^{-1}$ at 30 months and 14.77-43.83 q $ha^{-1}$ at 36months growth period. Further, it was noticed that significantly highest root yield was recorded with the closer plant spacing of 100 x 50 cm.

**Table-3(b) Lateral root length and girth of Shonak/Tetu (*Oroxylum indicum*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | | | |
|---|---|---|---|---|---|---|
| | 24 | 30 | 36 | 24 | 30 | 36 |
| **Plant Spacing (cm)** | | **Root length (cm)** | | **Root girth (cm)** | | |
| S1-(100 X 150 ) | 56.21 | 57.33 | 60.91 | 1.95 | 1.20 | 1.32 |
| S2-(100 X 100 ) | 46.61 | 48.40 | 58.65 | 1.18 | 1.22 | 1.25 |
| S3-(100 X 50 ) | 45.61 | 46.41 | 49.75 | 1.06 | 0.99 | 1.15 |
| SE (m) ± | 0.95 | 0.91 | 0.75 | 0.02 | 0.02 | 0.03 |
| CD at 5% | 2.78 | 2.66 | 2.20 | 0.06 | 0.06 | 0.10 |
| **FYM levels (t $ha^{-1}$)** | | | | | | |
| F 1 -0.0 | 38.39 | 43.56 | 48.23 | 0.86 | 0.96 | 1.10 |
| F 2 -2.0 | 48.17 | 50.94 | 57.67 | 0.98 | 1.15 | 1.17 |
| F 3 -4.0 | 51.02 | 54.34 | 58.63 | 1.34 | 1.17 | 1.25 |
| F 4 -6.0 | 60.33 | 54.01 | 61.22 | 1.40 | 1.26 | 1.45 |
| SE (m) ± | 1.09 | 1.05 | 0.86 | 0.02 | 0.02 | 0.04 |
| CD at 5% | 3.21 | 3.06 | 2.54 | 0.06 | 0.06 | 0.12 |
| **Interaction S x F** | | | | | | |
| S1F1 | 46.60 | 43.17 | 50.25 | 0.96 | 1.1 | 1.25 |
| S1F2 | 58.00 | 55.40 | 63.00 | 1.07 | 1.20 | 1.30 |
| S1F3 | 56.92 | 64.75 | 63.70 | 1.32 | 1.24 | 1.29 |
| S1F4 | 63.33 | 66.00 | 66.70 | 1.43 | 1.26 | 1.45 |
| S2F1 | 33.90 | 45.00 | 50.70 | 0.76 | 0.97 | 1.00 |
| S2F2 | 45.25 | 50.67 | 60.00 | 1.17 | 1.27 | 1.15 |
| S2F3 | 50.13 | 51.08 | 60.70 | 1.46 | 1.30 | 1.32 |
| S2F4 | 57.17 | 46.83 | 63.20 | 1.35 | 1.32 | 1.55 |
| S3F1 | 34.67 | 42.50 | 43.75 | 0.85 | 0.82 | 1.05 |
| S3F2 | 41.25 | 46.75 | 50.00 | 0.70 | 0.98 | 1.05 |
| S3F3 | 46.00 | 47.20 | 51.50 | 1.25 | 0.98 | 1.15 |
| S3F4 | 60.50 | 49.20 | 53.75 | 1.43 | 1.20 | 1.35 |
| SE (m) ± | 1.90 | 1.81 | 1.49 | 0.04 | 0.04 | 0.07 |
| CD at 5% | 5.56 | 5.31 | 4.39 | 0.12 | 0.12 | 0.20 |

Application of FYM at various levels significantly influenced the root yield and significantly highest root yield was noticed with the application 6 t FYM per hectare at all the growth period (24, 30 and 36 months) under study. The interaction effect was found to be significant at all the growth periods. The plant spacing of 100 x 150 cm with the application of 6 t FYM per hectare (S1xF4) recorded significantly highest root yield at 24, 30 and 36 months growth periods. These results are in agreement with the findings of Mohit Kumar and Rajesh Kumar (2013) and Adegun and Ayodele (2015). The application of organic manures influences the plant growth by enhancing root biomass thereby total root surface facilitates higher absorption of nutrients ultimately increase the biomass yield (Farhad *et al* ,2019).

**Physicochemical analysis of roots of Shonak/Tetu (*Oroxylum indicum*) as influenced by plant spacing and FYM levels.**

**Table- 4(a) Relative dry root yield of completely uprooted plants of Shonak/Tetu (*Oroxylum indicum*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | | | |
|---|---|---|---|---|---|---|
| | 6 | 12 | 18 | 6 | 12 | 18 |
| **Plant Spacing (cm)** | **Dry root yield (g plant$^{-1}$)** | | | **Dry root yield (q ha$^{-1}$)** | | |
| S1-(100 X 150 ) | 6.89 | 43.43 | 259.75 | 0.45 | 2.89 | 17.33 |
| S2-(100 X 100 ) | 5.75 | 42.50 | 206.25 | 0.57 | 4.25 | 20.64 |
| S3-(100 X 50 ) | 4.71 | 36.25 | 188.25 | 0.94 | 7.25 | 37.68 |
| SE (m) ± | 0.21 | 0.59 | 4.68 | 0.02 | 0.07 | 0.74 |
| CD at 5% | 0.62 | 1.74 | 13.74 | 0.06 | 0.21 | 2.18 |
| **FYM levels (t ha$^{-1}$)** | | | | | | |
| F 1 -0.0 | 4.39 | 35.61 | 210.33 | 0.50 | 4.21 | 25.41 |
| F 2 -2.0 | 4.72 | 40.36 | 207.00 | 0.55 | 4.72 | 23.70 |
| F 3 -4.0 | 5.53 | 42.11 | 224.00 | 0.63 | 4.98 | **25.14** |
| F 4 -6.0 | 8.50 | 44.83 | 231.00 | 0.95 | 5.30 | 25.61 |
| SE (m) ± | 0.24 | 0.68 | 5.41 | 0.02 | 0.08 | 0.86 |
| CD at 5% | 0.72 | 2.01 | 15.87 | 0.07 | 0.25 | 2.52 |
| **Interaction S x F** | | | | | | |
| S1F1 | 5.00 | 38.00 | 223.00 | 0.33 | 2.53 | 14.87 |
| S1F2 | 5.33 | 43.25 | 247.00 | 0.35 | 2.88 | 16.48 |
| S1F3 | 6.75 | 45.00 | 283.00 | 0.45 | 3.00 | 18.88 |
| S1F4 | 10.50 | 47.50 | 286.00 | 0.70 | 3.17 | 19.08 |
| S2F1 | 4.50 | 36.83 | 203.00 | 0.45 | 3.68 | 20.32 |
| S2F2 | 4.83 | 43.17 | 202.00 | 0.48 | 4.32 | 20.22 |
| S2F3 | 5.17 | 43.33 | 213.00 | 0.52 | 4.33 | 21.32 |
| S2F4 | 8.50 | 46.67 | 207.00 | 0.85 | 4.67 | 20.72 |
| S3F1 | 3.67 | 32.00 | 205.00 | 0.73 | 6.40 | 41.03 |
| S3F2 | 4.00 | 34.67 | 172.00 | 0.80 | 6.94 | 34.42 |
| S3F3 | 4.67 | 38.00 | 176.00 | 0.93 | 7.61 | 35.23 |
| S3F4 | 6.50 | 40.33 | 200.00 | 1.30 | 8.07 | 40.03 |
| SE (m) ± | 0.42 | 1.19 | 9.37 | 0.04 | 0.14 | 1.48 |
| CD at 5% | 1.24 | 3.49 | 27.48 | 0.12 | 0.43 | 4.37 |

The data (Table 5) on water soluble extractive values revealed that the various plant spacing had influenced the WSE and highest values of WSE were noticed the closer spacing i.e. planting at 100 x 50 cm. The manurial treatments i.e. application of different levels of Farm Yard Manure under the plant spacing of 100 x 150 to 100 x 50 cm recorded favourable effect on WSE, however the results were non consistent. On the basis of general mean the WSE values were in the range of 14.08-54.15 per cent in the roots harvested from 6th months onwards up to 36th months at an interval of 6 months growth period. Further, it was observed that the WSE values (54.15per cent) was highest in the roots harvested at 18th months (i.e. December 2009) followed by WSE (52.51per cent) recorded at 6th months (i.e. December 2008) and WSE (42.61per cent) observed at 12th months (i.e. June, 2009).Comparatively lowest WSE values were noticed in the roots harvested at 36th months (June, 2011), followed by 30th months (December, 2010) and 24th months (June, 2010).

**Table- 4(b) Relative lateral dry root yield of Tetu (*Oroxylum indicum*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | | | |
|---|---|---|---|---|---|---|
| | 24 | 30 | 36 | 24 | 30 | 36 |
| **Plant Spacing (cm)** | **Dry root yield (g plant$^{-1}$)** | | | **Dry root yield (q ha$^{-1}$)** | | |
| S1-(100 X 150 ) | 183.58 | 261.98 | 309.37 | 12.24 | 17.47 | 20.64 |
| S2-(100 X 100 ) | 169.41 | 175.66 | 244.90 | 16.95 | 17.58 | 24.50 |
| S3-(100 X 50 ) | 115.52 | 125.55 | 175.33 | 23.12 | 25.13 | 35.09 |
| SE (m) ± | 1.82 | 5.87 | 4.67 | 0.22 | 0.66 | 0.50 |
| CD at 5% | 5.36 | 17.23 | 13.70 | 0.67 | 1.95 | 1.49 |
| **FYM levels (t ha$^{-1}$)** | | | | | | |
| F 1 -0.0 | 98.08 | 110.97 | 172.83 | 11.49 | 12.64 | 18.50 |
| F 2 -2.0 | 139.93 | 162.08 | 219.97 | 15.97 | 17.60 | 25.53 |
| F 3 -4.0 | 185.50 | 223.89 | 266.66 | 19.81 | 23.11 | 29.12 |
| F 4 -6.0 | 201.17 | 253.97 | 313.33 | 22.48 | 26.88 | 33.83 |
| SE (m) ± | 2.11 | 6.78 | 5.39 | 0.26 | 0.76 | 0.58 |
| CD at 5% | 5.18 | 19.90 | 15.82 | 0.77 | 2.25 | 1.72 |
| **Interaction S x F** | | | | | | |
| S1F1 | 115.00 | 132.20 | 221.50 | 7.67 | 8.82 | 14.77 |
| S1F2 | 146.00 | 215.50 | 240.00 | 9.74 | 14.38 | 16.01 |
| S1F3 | 237.00 | 336.17 | 342.00 | 15.81 | 22.43 | 22.82 |
| S1F4 | 236.33 | 364.00 | 434.00 | 15.77 | 24.28 | 28.96 |
| S2F1 | 90.67 | 110.50 | 187.00 | 9.07 | 11.06 | 18.71 |
| S2F2 | 166.00 | 157.34 | 234.60 | 16.61 | 15.74 | 23.48 |
| S2F3 | 203.00 | 202.30 | 271.00 | 20.32 | 20.24 | 27.12 |
| S2F4 | 218.00 | 232.50 | 287.00 | 21.82 | 23.27 | 28.72 |
| S3F1 | 88.60 | 90.20 | 110.00 | 17.73 | 18.05 | 22.02 |
| S3F2 | 107.80 | 113.40 | 185.33 | 21.58 | 22.70 | 37.09 |
| S3F3 | 116.50 | 133.20 | 187.00 | 23.32 | 26.66 | 37.43 |
| S3F4 | 149.20 | 165.40 | 219.00 | 29.86 | 33.10 | 43.83 |
| SE (m) ± | 3.65 | 11.75 | 9.34 | 0.45 | 1.33 | 1.01 |
| CD at 5% | 10.72 | 34.47 | 27.41 | 1.34 | 3.90 | 2.98 |

The data on alcohol soluble extractive values revealed that the various plant spacing and the manurial treatments i.e. application of different levels of Farm Yard Manure did not influenced the ASE values in the roots of Shonak. On the basis of general mean the ASE values were in the range of 5.37-9.64 per cent in the roots harvested from 6$^{th}$ months onwards up to 36$^{th}$ months at an interval of 6 months growth period. Further, it was observed that the ASE values (9.64%) was highest in the roots harvested at 30$^{th}$ months (i.e. December, 2010) followed by ASE (8.57%) recorded at 12$^{th}$ months (i.e. June, 2009) and ASE (7.28%) observed at 24$^{th}$ months (i.e. June, 2010). Comparatively lowest ASE values (5.37%) were noticed in the roots harvested at 36$^{th}$ months (June,2011), followed by 6$^{th}$ months (December, 2008) and 18$^{th}$ months (December, 2009). On the basis of general mean the total ash values were in the range of 3.19-5.65per cent and acid insoluble ash values were in the range of 0.64-2.82per cent in the roots harvested from 6$^{th}$ months onwards up to 36$^{th}$ months at an interval of 6 months growth period (Table 6).

As the results obtained on physico-chemical constituents were not consistent with the manurial treatments i.e. application of different levels of FYM, the composite samples for each plant spacing(i.e.$S_1$,$S_2$ and $S_3$) with FYM @ 2 t FYM per hectare were analysed for phyto-chemical constituents (Table 7).

The total flavonoids values were in the range of 1.07-2.63 per cent, Alkaloid values were in the range of 0.32-1.08 per cent, Phenols values were comparatively higher and found in the range of 1.95-2.57 per cent and Glycosides values were also higher and noticed in the range of 3.57-18.30 per cent in the roots harvested from 6$^{th}$ months onwards up to 36$^{th}$ months at an interval of 6 months growth period. Further, it is observed that the values of these phyto-chemical constituents were maximum in the roots harvested at 18$^{th}$ months onwards.

The WSE values reported/observed in the roots of ,Shonak harvested at 18-24$^{th}$ months under the study conforms the accepted limits and is having higher relevance in context of Ayurvedic methods of drug usage as these values are indicative of phyto-constituents in a given quantity medicinal plant material (Padma, *et.al* 2010).

Further, it is observed that the values of these phyto-chemical constituents were maximum in the roots of the brihat-panchmoola species under study harvested at 18$^{th}$-24$^{th}$ months onwards. Phyto-chemicals, polyphenols are largely recognized as anti-inflammatory, antiviral, antimicrobial and antioxidant agent (Narayana, *et.al.2001*). As such, phenolics and flavanoides constitute major group of compounds which act as primary antioxidants (Adesegun *et.al.* 2009) are known to react with hydroxyl radicals (Hussain *et.al.*1987) super-oxide anion radicals (Afanaslev *et.al.* 1989), lipid peroxiradicals (Torel *et.al.*1986),protect DNA from oxidative damage inhibitory against tumor cells and possess anti-inflammatory and antimicrobial properties. Thus, the results of this study signify that the roots of Shonak/ Tetu(*Oroxylum indicum*) at the age of 18 months growth period could be a source of natural antioxidant and anti-inflammatory drug.

## CONCLUSION

Considering various aspects such as dry root yield, per cent WSE, total alkaloids, total flavonoids, total glycosides standards provided by Ayurvedic Pharmacopoeia of India and the most importantly the feasibility and cost effectiveness of root harvesting, it can be concluded that the roots *Oroxylum indicum* (Shonak) at the age of 18 months. The plant spacing of 100 x 100-150 cm with FYM application @ 2 t $ha^{-1}$ found superior among all the treatments under study.

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**Table 7 : Total flavonoids, Alkaloid, Phenols and Glycosides in Shonak/Tetu (*Oroxylum indicum*) roots as influenced by different plant spacing.**

| **Treatment combinations** | **Growth Period (Months)** | | | | |
|---|---|---|---|---|---|
| | **12** | **18** | **24** | **30** | **36** |
| **Plant spacing x FYM levels** | | | **Total Flavonoids (%)** | | |
| **S 1 100 x 150 cm x**F 2 2.0 t FYM $ha^{-1}$ | 1.20 | 5.30 | 2.65 | 1.33 | 1.80 |
| S 2 100 x 100 cm xF 2 2.0 t FYM $ha^{-1}$ | 1.17 | 1.10 | 2.17 | 1.17 | 2.11 |
| S 3 100 x 50 cm xF 2 2.0 t FYM $ha^{-1}$ | — | 1.50 | 1.20 | 0.71 | 1.75 |
| Mean | 1.19 | 2.63 | 2.01 | 1.07 | 1.89 |
| | | | **Alkaloid (%)** | | |
| **S 1 100 x 150 cm x**F 2 2.0 t FYM $ha^{-1}$ | 0.20 | 0.13 | 0.24 | 1.50 | 1.16 |
| S 2 100 x 100 cm xF 2 2.0 t FYM $ha^{-1}$ | 0.83 | 0.12 | 0.47 | 0.99 | 1.13 |
| S 3 100 x 50 cm xF 2 2.0 t FYM $ha^{-1}$ | — | 0.70 | 1.30 | 0.60 | 0.94 |
| Mean | 0.52 | 0.32 | 0.67 | 1.03 | 1.08 |
| | | | **Phenols (%)** | | |
| **S 1 100 x 150 cm x**F 2 2.0 t FYM $ha^{-1}$ | 1.90 | 2.14 | 2.32 | 2.19 | 2.40 |
| S 2 100 x 100 cm xF 2 2.0 t FYM $ha^{-1}$ | 2.00 | 2.28 | 2.28 | 2.00 | 2.70 |
| S 3 100 x 50 cm xF 2 2.0 t FYM $ha^{-1}$ | — | 2.77 | 2.36 | 2.26 | 2.60 |
| Mean | 1.95 | 2.40 | 2.32 | 2.15 | 2.57 |
| | | | **Glycosides (%)** | | |
| **S 1 100 x 150 cm x**F 2 2.0 t FYM $ha^{-1}$ | 7.50 | 2.50 | 8.62 | 19.61 | 15.67 |
| S 2 100 x 100 cm xF 2 2.0 t FYM $ha^{-1}$ | 6.30 | 4.40 | 13.16 | 19.60 | 14.38 |
| S 3 100 x 50 cm xF 2 2.0 t FYM $ha^{-1}$ | — | 3.80 | 9.44 | 15.70 | 15.93 |
| Mean | 6.90 | 3.57 | 10.41 | 18.30 | 15.33 |


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# Influence of Fertigation on Yield, Quality and Economics of Potato

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## ABSTRACT

The field experiment was conducted during *Rabi* season in 2018-19 to study the effect of fertigation on yield, quality and economics of potato. The experiment was laid out in a Randomized Block Design with treatments consisting of seven NPK levels replicated three times. The results showed that drip fertigation of 225:200:175 dose of N, P and K at 3rd day interval after planting markedly increased yield attributes like number of tuber plant$^{-1}$, weight of tuber (g), fresh weight of tuber plant$^{-1}$ (g), yield of Tuber plot$^{-1}$ (kg), tuber yield (q ha$^{-1}$), quality attributes like starch and protein %) and economics of potato. Further, this method had improved yield and quality of potato. The highest net returns (Rs. 2,55,333 ha$^{-1}$) and maximum B: C ratio (2.69) was recorded with application of 225:200:175 kg NPK ha$^{-1}$.

Potato (*Solanum tuberosum* L.) belongs to family Solanaceae and is one of the most important vegetable cum starch supplying crop having high production per unit area per unit time. The potato is the third most important food crop in the world after Rice and Wheat which is consumed by more than a billion people worldwide. Potato, an underground tuber occupies prime position among the cash crops in India.

Potato is grown in almost all states of India except Kerala. The leading states in terms of area, production and productivity are Gujarat, Uttar Pradesh, Bihar, West Bengal and Punjab. Potato contains practically all essential dietary constituents like carbohydrates, essential nutrients, protein, vitamins and minerals. Normally some potato tubers of Indian cultivars contain less than 20 mg glycoalkaloids per 100 g fresh weight and cause no harmful effects.

The potato plant consumes high level of nutrients during a short growth period (90 days). Variations in soil fertility affect on several characters that influence the growth and yield. Good vegetative growth and tuberization, which lead to good yield, are possible only when adequate quantities of mineral nutrients are supplied (Benepal 1967). One ton of potato tubers remove 5 kg N, 1.8 kg $P_2O_5$ and 9 kg $K_2O$ (Shnek, 1994). Significant response to NPK application on potato crops has also been reported by Singh and Singh (1995) and Singh *et al.* (1993). Similarly, vegetative growth and yield performance of cultivar varies depending on the soil and climatic condition. Significant potato responses to NPK application have been reported by various workers in different agro-climatic condition and optimum dose of NPK varied with the soil and potato varieties.

Fertigation of water soluble fertilizers through drip ensures even distribution of nutrients and water to plant with precise timing to meet crop nutrient demand, while minimizing nutrients losses through leaching, reduces environmental pollution and soil erosion. However, response of different varieties varies with management practices such as methods of nutrient application and irrigation. Keeping these points in view the present investigation was planned to study the effect of different methods of drip fertigation on yield,quality and economics of potato.

## MATERIAL AND METHODS

Field experiment was conducted at Instructional Farm, Department of Vegetable Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *rabi* season in 2018-19. The soil of the experimental site was clay loamy in texture with pH (7.18). The experiment was laid out in Randomized Block Design with seven treatments i.e; $T_1$-100:75:50 NPK kg ha$^{-1}$, $T_2$-125:100:75 NPK kg ha$^{-1}$, $T_3$-150:125:100 NPK kg ha$^{-1}$, $T_4$-175:150:125 NPK kg ha$^{-1}$, $T_5$-200:175:150 NPK kg ha$^{-1}$, $T_6$-225:200:175 NPK kg ha$^{-1}$and $T_7$-250:200:200 NPK kg ha$^{-1}$ Fertigation with 3rd days of interval after 10 days planting. Water soluble fertilizer sources used during experimentation were urea, phosphoric acid and sulphur of potash. The Kufri Pukhraj

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variety was planted on broad bed furrow with spacing 45 x 20 cm.

Yield attributes like number of tuber per plant, weight of tuber (g), fresh weight of tuber per plant (g), yield of tuber per plot (kg), tuber yield (q $ha^{-1}$) of potato were recorded at harvest and quality attributes like starch and protein.

## RESULTS AND DISCUSSION

### Yield and Yield Attributing Parameters

The data presented showed that the maximum weight of tuber (41.66 g) was obtained when 225:200:175 NPK kg $ha^{-1}$ was applied, which was significantly at par with application of 250:200:200 NPK kg $ha^{-1}$, 200:175:150 NPK kg $ha^{-1}$ and 175:150:125 NPK kg $ha^{-1}$. The maximum number of tubers $plant^{-1}$ (6.27) was recorded with application of 225:200:175 NPK kg $ha^{-1}$). Which was at par with application of 200:175:150 NPK kg $ha^{-1}$, 150:125:100 NPK kg $ha^{-1}$, 175:150:125 NPK kg $ha^{-1}$ and 250:200:200 NPK kg $ha^{-1}$.

Significantly maximum fresh weight of tuber $plant^{-1}$ (261.20 g), tuber yield $plot^{-1}$ (5.22 kg) and yield $ha^{-1}$ (290 q) were obtained with application of 225:200:175 kg NPK $ha^{-1}$, which found statistically at par(240.22 g) with application of 200:175:150 NPK kg $ha^{-1}$. However, the minimum fresh weight of tuber (149.11 g), tuber yield $plot^{-1}$ (2.98 kg) and yield per hectare (165.55 q) was recorded in treatment with 100:75:50 kg NPK $ha^{-1}$. These results are in close conformity with the findings reported by Singh *et al*. 2000. Favorable effect of NPK in promoting yield and yield parameters might be due to the fact that the NPK improved the carbohydrate content of the plants and it extended tuber growth, which ultimately increased the total yield and yield parameters of potato.

### Quality Parameters

The data in Table 2 revealed that the effect of NPK levels on quality parameters was found to be non significant. However, there was numerical increase in starch and protein content particularly at higher level of NPK 250:200:200 and 225:200:175 kg $ha^{-1}$.

The amount of starch accumulated is a function of the rate of photosynthesis, translocation of photosynthates from leaves to tubers and subsequent conversion to starch (Praveen *et al*., 2008). Potassium which was applied along with nitrogen played a greater role in translocation of sugars from leaves to tubers and synthesis of starch. Similar results were also reported by Sujatha and Krishnappa (1995).

The increase in proteint content might be due to the synergetic effect of N and K in absorption and their role in protein synthesis, translocation of amino acids and their polymerization (Falak *et al.,* 2011).

**Table 1. Effect of NPK levels on yield attributing parameters of potato**

| Treatments (NPK kg $ha^{-1}$) | Number of tuber $plant^{-1}$ | Weight of tuber ( g) | Fresh weight of tuber (g) $plant^{-1}$ | Yield of Tuber $plot^{-1}$ (Kg) | Tuber Yield q $ha^{-1}$ |
|---|---|---|---|---|---|
| $T_1$ - 100:75:50 | 4.87 | 30.62 | 149.11 | 2.98 | 165.55 |
| $T_2$ - 125:100:75 | 5.20 | 34.60 | 179.92 | 3.59 | 199.44 |
| $T_3$ - 150:125:100 | 5.73 | 36.16 | 207.19 | 4.14 | 230.00 |
| $T_4$ - 175:150:125 | 5.60 | 38.60 | 216.16 | 4.32 | 240.00 |
| $T_5$ - 200:175:150 | 5.93 | 40.51 | 240.22 | 4.80 | 266.66 |
| $T_6$ - 225:200:175 | 6.27 | 41.66 | 261.20 | 5.22 | 290.00 |
| $T_7$ - 250:200:200 | 5.47 | 41.12 | 224.92 | 4.49 | 249.44 |
| S.E. (m) $\pm$ | 0.26 | 1.594 | 9.51 | 0.24 | 8.26 |
| CD at 5 % | 0.82 | 4.966 | 29.63 | 0.77 | 25.73 |

**Table 2. Effect of NPK levels on quality attributing parameters of potato**

| Treatments (NPK $ha^{-1}$) | Starch (%) | Protein (%) |
|---|---|---|
| $T_1$ - 100:75:50 | 10.00 | 0.40 |
| $T_2$ - 125:100:75 | 10.67 | 0.83 |
| $T_3$ - 150:125:100 | 10.87 | 1.00 |
| $T_4$ - 175:150:125 | 11.03 | 1.33 |
| $T_5$ - 200:175:150 | 11.45 | 1.65 |
| $T_6$ - 225:200:175 | 12.20 | 2.50 |
| $T_7$ - 250:200:200 | 11.79 | 2.00 |
| S.E. (m) ± | 1.73 | 0.48 |
| CD at 5 % | - | - |

## Economics

Cost of cultivation per hectare is presented in Table 3 and found maximum (Rs. 151990 $ha^{-1}$) with application of 250:200:200 kg NPK $ha^{-1}$ whereas, the lowest cost of cultivation (Rs.112310 $ha^{-1}$) was found when 100:75:50 kg NPK $ha^{-1}$ was applied. However, the maximum gross income (Rs. 406000.00) and net income (Rs. 255333) was obtained with application of 225:200:175 kg NPK $ha^{-1}$. The maximum B: C ratio (2.69) was obtained when 225:200:175 kg NPK $ha^{-1}$ applied which was at par (2.61) with treatment 200:175:150 NPK $ha^{-1}$.

**Table 3. Economics of potato crops due to different NPK levels of fertigation**

| Treatments (NPK $ha^{-1}$) | Tuber yield (q $ha^{-1}$) | Cost of cultivation (Rs $ha^{-1}$) | Gross monetary return (Rs $ha^{-1}$) | Net monetary return (Rs $ha^{-1}$) | B:C ratio |
|---|---|---|---|---|---|
| $T_1$ - 100:75:50 | 165.55 | 112310.00 | 231770.00 | 119460 | 2.06 |
| $T_2$ - 125:100:75 | 199.44 | 119982.00 | 279216.00 | 159234 | 2.33 |
| $T_3$ - 150:125:100 | 230.00 | 127655.00 | 322000.00 | 194345 | 2.52 |
| $T_4$ - 175:150:125 | 240.00 | 135325.00 | 336000.00 | 200675 | 2.48 |
| $T_5$ - 200:175:150 | 266.66 | 142995.00 | 373324.00 | 230329 | 2.61 |
| $T_6$ - 225:200:175 | 290.00 | 150667.00 | 406000.00 | 255333 | 2.69 |
| $T_7$ - 250:200:200 | 249.44 | 151990.00 | 349216.00 | 197226 | 2.30 |
| S.E. m.± | 8.26 | 4364.35 | 786.79 | 526.44 | 0.03 |
| CD at 5 % | 25.73 | 13596.86 | 2451.21 | 1640.1 | 0.09 |

## CONCLUSION

It can be concluded that, application of 225:200:175 NPK kg $ha^{-1}$ through drip fertigation recorded maximum yield attributes like number of tuber $plant^{-1}$, fresh weight of tuber $plant^{-1}$, and tuber yield $ha^{-1}$, higher monetary return and B:C ratio in potato crop.

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# Effect of Plant Geometry and Organic Manure on Short Term Root Biomass Production with Quality of *Aegle marmelos* - a Species of Brihatpanchmool

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## ABSTRACT

To assess the root biomass in short term period *Aegle marmelos* (Bael/Bilva) a tree species was planted under different geometry and soil fertility during *Kharif* season 2008-09 the treatments comprising of three plant spacings 100 x 150 cm (S1-6,666 Plant population ha$^{-1}$),100 x 100 cm (S2-10,000 Plant population ha$^{-1}$), 100 x 50 cm (S3-20,000 Plant population ha$^{-1}$) and four levels viz.0.0 ,2.0 ,4.0 ,6.0 t ha$^{-1}$.with the plot size of -6.0 x 6 .0 m. The observations on plant height, No. of branches, root length and girth, fresh and dry root yield were recorded up to 3 years at an interval of six months growth period. As there was no significant growth at 6 months period, the plants of Bilva/Bael *(Aegle marmelos)* were completely uprooted at 12 and 18 month's growth period for recording the root yield including tap root. The woody and hard tap root is rather less pharmaceutical important and therefore at 24, 30 and 36 months growth period only lateral roots were harvested. At 12 months of growth stage, the root length, root girth and dry root yield plant$^{-1}$ and total glycosides were highest with the plant spacing of 100 x 150 cm and FYM @ 2 t ha$^{-1}$ ($S_1$ x $F_2$). After 18 months stage, highest dry root yield and phytochemical values were observed with the plant spacing of 100 x 150 cm and FYM @ 2 t ha$^{-1}$ ($S_1$ x $F_2$). Although the water soluble extractive (% WSE) values were much above the required value i.e. 7 per cent as per the standards given in Ayurvedic Pharmacopoeia of India. Since the harvesting of roots after 18 months was very difficult with increased requirement of labour, time and cost, lateral roots were harvested from 24 months and analysed. At 24 months stage, highest plant height, no of branches, root length, dry root yield and per cent water soluble extractives were obtained with the plant spacing of 100 x 150 cm and FYM @ 2 t ha$^{-1}$ ($S_1$ x $F_2$). However, root girth, per cent ASE, total alkaloids, total phenols and total glycosides were found to be highest with the plant spacing of 100 x100 cm with FYM 2.0 t ha. ($S_2$ x $F_2$). The values of total glycosides were highest amongst all the growth stages and treatments. Glycosides are the important bioactive group of Bilva as reported in Ayurvedic pharmacopoeia of India. The per cent WSE and per cent ASE values were as per the standards given in Ayurvedic Pharmacopoeia of India i.e. higher than 7 per cent. Although the values of total flavonoid were higher at the age of 30 months, the dry root yield and the total glycosides were less than 24 month age. Also the per cent ASE was found to be much less with all the treatments than 24 month age.

Many of the manufacturing units of Ayurvedic drugs are experiencing the shortage of raw material for the plant products from medicinal plant species being used as a Dashmool. The supply of the raw material particularly to that of root based material from trees of dashmool group is very-very meagre and hardly there are reliable data available which support supply scenario. This kind of short supply may lead to the use of either substitutes or in a very low quantity in the ayurvedic formulations and ultimately affect the efficacy of the formulations. In view of above, it is imperative to develop the agrotechnologies of these species. Hence, there is an urgent need for an intervention to develop and conserve the resource base for dashmool. The present investigation was carried out with the objectives to develop the agronomic protocols for high density, short term plantation for Bilva/Bael (*Aegle marmelos*) a species of Brihatpanchmool and to study the yielding potential as influenced by age of the plant and time of harvesting.

Dashmoola is a fixed dose combination of 10 roots obtained from 5 tree species *Aegle marmelos* (Bilva/ Bael) is one of them, 2 shrub / under shrub species and 3 herb species. These species belong to six different families of Angiosperms: Verbenaceae (2 species), Fabaceae (2 species), Solanaceae (2 species), Bignoniaceae (2 species), Rutaceae (1 species) and Zygophyllaceae (1 species).Dashmoolarishta prepared from these species can be used as a tonic to strengthen the system. When the immune system is depleted and is not throwing off

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fevers the decoction can cause diaphoresis and release the trapped *Ama* toxins. It is also good for influenza, colds, neuralgia, and headaches. One-quarter cup consumed daily for twenty-one days functions as a rapid cell rejuvenator.

## MATERIAL AND METHODS

To assess the growth and root yield performance of Bael/Bilva a tree species was planted under different geometry and soil fertility during *Kharif* season 2008-09 the treatments comprising of three plant spacings 100 x 150 cm (S1-6,666 Plant population $ha^{-1}$),100 x 100 cm (S2-10,000 Plant population $ha^{-1}$) ,100 x 50 cm (S3-20,000 Plant population $ha^{-1}$) and four levels viz.0.0 ,2.0 ,4.0 ,6.0 t $ha^{-1}$ with the plot size of -6.0 x 6.0 m. The observations on plant height, No. of branches, root length and girth , fresh and dry root yield were recorded up to 3 years at an interval of six months growth period. As there was no significant growth,the plants of Bael*(Aegle marmelos )*, were completely uprooted at 12 and 18 month's growth period for recording the root yield including tap root. The

**Table 1. Relative plant height (cm) of Bilva/Bael (*Aegle marmelos*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | | |
|---|---|---|---|---|---|
| | 12 | 18 | 24 | 30 | 36 |
| **Plant spacing (cm)** | | | **Plant Height (cm)** | | |
| $S_1$ - (100 X 150 ) | 64.38 | 94.81 | 136.05 | 146.00 | 161.95 |
| $S_2$ - (100 X 100 ) | 66.46 | 110.92 | 137.91 | 147.65 | 174.67 |
| $S_3$ - (100 X 50 ) | 67.04 | 112.53 | 144.50 | 153.08 | 173.19 |
| SE (m) ± | 0.69 | 5.01 | 2.33 | 3.77 | 4.14 |
| CD (P=0.05) | 2.04 | 14.70 | 6.83 | 11.06 | 13.14 |
| **FYM levels (t $ha^{-1}$)** | | | | | |
| $F_1$ - 0.0 | 60.11 | 99.50 | 120.01 | 133.01 | 161.13 |
| $F_2$ - 2.0 | 66.54 | 104.56 | 133.66 | 138.58 | 165.45 |
| $F_3$ - 4.0 | 67.98 | 115.31 | 144.22 | 151.15 | 172.41 |
| $F_4$ - 6.0 | 69.68 | 104.97 | 160.05 | 172.89 | 180.75 |
| SE (m) ± | 0.80 | 5.78 | 2.69 | 4.36 | 4.78 |
| CD at 5% | 2.35 | 16.97 | 13.66 | 12.77 | 14.02 |
| **Interaction S x F** | | | | | |
| $S_1F_1$ | 58.00 | 93.33 | 109.45 | 129.00 | 150.30 |
| $S_1F_2$ | 65.50 | 102.75 | 135.64 | 134.75 | 160.00 |
| $S_1F_3$ | 66.33 | 108.00 | 142.50 | 155.25 | 168.75 |
| $S_1F_4$ | 67.67 | 75.17 | 156.60 | 165.00 | 168.75 |
| $S_2F_1$ | 61.00 | 102.50 | 126.83 | 139.83 | 168.83 |
| $S_2F_2$ | 66.83 | 103.83 | 130.60 | 142.60 | 169.67 |
| $S_2F_3$ | 67.17 | 118.00 | 139.40 | 145.50 | 179.67 |
| $S_2F_4$ | 70.83 | 119.33 | 154.80 | 162.67 | 180.50 |
| $S_3F_1$ | 61.33 | 102.67 | 123.75 | 130.20 | 164.25 |
| $S_3F_2$ | 67.30 | 107.09 | 134.75 | 138.40 | 166.67 |
| $S_3F_3$ | 70.43 | 119.92 | 150.75 | 152.70 | 168.82 |
| $S_3F_4$ | 70.55 | 120.42 | 168.75 | 191.00 | 193.00 |
| SE (m) ± | 1.39 | 10.02 | 4.66 | 7.54 | 8.28 |
| CD at 5% | 4.07 | 29.4 | 13.66 | 22.13 | 24.28 |

woody and hard tap root is rather less pharmaceutical important and therefore at 24, 30 and 36 months growth period only lateral roots were harvested. The physicochemical and phyto-chemical analysis of the roots harvested at 12, 18, 24, 30 and 36 months growth period was carried out.by standard methods (Torel, *et al*,1986; Agrawal and Paridhavi, 2007 and Padma,*et al*., 2010 ).

## RESULTS AND DISCUSSION

**Plant height**

As Bael (*Aegle marmelos)* is very slow growing species the growth observations *were* recorded from the 12 months growth period onwards**.** The data presented in Table-1 revealed that the plant height was successively found to increase with each growth period. Further, it was noticed that significantly maximum plant height was recorded with the closer plant spacing 100 x 50 cm except the plant height recorded at 36 months was highest with the plant spacing of 100 x 100 cm, however it was at par with the plant spacing of 100 x 50 cm

. Application of FYM at various levels significantly influenced the plant height and significantly maximum plant height was noticed with the application 6 t FYM per hectare at all the growth periods, except the plant height recorded at 18 months growth period under study. However, it was at par with 4 t FYM $ha^{-1}$.The interaction effect was found to be significant at all the growth periods. The plant spacing of 100 x 50 cm with the application of 6 t FYM per hectare (S3xF4) recorded significantly maximum plant height at all the growth periods.

**No. of branches**

The data presented in Table 2 revealed that the number of branches was also successively found to increase with each growth period. Further, it was noticed that significantly maximum number of branches were recorded with the wider plant spacing 100 x 150 cm, except the branches recorded at 12 and 36 months growth period were maximum with the plant spacing of 100 x 100 cm.

Application of FYM at various levels significantly influenced the number of branches per plant and significantly maximum branches were noticed with the application 6 t FYM $ha^{-1}$ at all growth periods. The interaction effect was found to be significant at all the growth periods. The plant spacing of 100 x 100 cm with the application of 6 t FYM $ha^{-1}$ (S2xF4) recorded significantly maximum branches $plant^{-1}$ at 12, 24 and 36 months growth period. However, number of branches were noticed significantly highest at 18 and 30 months growth periods under the plant spacing 100 x 150 cm with 6 t FYM per hectare (S1xF4).

**Root length and girth**

The data presented in Table-3(a) revealed that the root length and girth of completely uprooted plants of Bael at 12 and 18 months growth periods were successively found to increase with each growth period. Further, it was noticed that significantly maximum root length and girth was recorded with the wider plant spacing 100 x 150 cm.

Application of FYM at various levels significantly influenced the root length and girth and significantly maximum root length and root girth was noticed with the application 6 t FYM $ha^{-1}$ at all the growth periods under study, except the root girth recorded at 12 and 18 months growth periods. The root girth was maximum with 4 t FYM, however, it was at par with 6 t FYM $ha^{-1}$. The interaction effect was found to be significant at all the growth periods. The plant spacing of 100 x 150 cm with the application of 6 t FYM $ha^{-1}$ ($S_1xF_4$) recorded significantly maximum root length and girth at all the growth periods except the root girth recorded at 18 months growth period. The root length noticed at 18 months growth period under the plant spacing 100 x 150 cm with 4 t FYM $ha^{-1}$ ($S_1xF_3$) was significantly highest, however at par with plant spacing of 100 x 150 cm and the application of 6 t FYM $ha^{-1}$ ($S_1xF_4$).

During the growth periods of 24, 30 and 36 months only lateral roots were harvested and the data generated on the lateral root length and girth is presented in Table 3(b). The lateral root length and girth was also successively found to increase with each growth period. Further, it was noticed that significantly maximum root length and girth was recorded with the wider plant spacing 100 x 150 cm.

Application of FYM at various levels significantly influenced the root length and girth and

**Table 2. Relative number of branches of Bilva/Bael (*Aegle marmelos*) as influenced by plant spacing and FYM levels**

| Treatments | Growth Period (Months) | | | | |
|---|---|---|---|---|---|
| | 12 | 18 | 24 | 30 | 36 |
| **Plant spacing (cm)** | | | **No. of branches** | | |
| $S_1$ - (100 X 150 ) | 2.17 | 7.69 | 7.75 | 8.54 | 11.14 |
| $S_2$ - (100 X 100 ) | 2.21 | 7.12 | 7.47 | 8.45 | 11.67 |
| $S_3$ - (100 X 50 ) | 2.04 | 5.84 | 6.14 | 6.48 | 11.38 |
| SE (m) ± | 0.07 | 0.08 | 0.14 | 0.12 | 0.23 |
| CD (P=0.05) | 0.22 | 0.25 | 0.42 | 0.35 | 0.67 |
| **FYM levels (t ha$^{-1}$)** | | | | | |
| $F_1$ - 0.0 | 1.94 | 6.14 | 6.19 | 7.40 | 9.89 |
| $F_2$ - 2.0 | 1.96 | 6.94 | 6.82 | 7.75 | 11.31 |
| $F_3$ - 4.0 | 2.29 | 7.01 | 7.01 | 8.02 | 11.61 |
| $F_4$ - 6.0 | 2.35 | 7.44 | 8.47 | 8.13 | 12.77 |
| SE (m) ± | 0.09 | 0.10 | 0.17 | 0.14 | 0.26 |
| CD at 5% | 0.25 | 0.29 | 0.49 | 0.41 | 0.77 |
| **Interaction S x F** | | | | | |
| $S_1F_1$ | 2.00 | 6.75 | 6.50 | 7.80 | 10.25 |
| $S_1F_2$ | 2.00 | 7.75 | 7.75 | 8.50 | 11.00 |
| $S_1F_3$ | 2.33 | 8.00 | 7.75 | 8.87 | 10.50 |
| $S_1F_4$ | 2.33 | 8.25 | 9.00 | 9.00 | 12.80 |
| $S_2F_1$ | 2.00 | 6.33 | 6.80 | 8.20 | 9.67 |
| $S_2F_2$ | 2.00 | 7.50 | 7.20 | 8.40 | 11.17 |
| $S_2F_3$ | 2.33 | 6.83 | 6.67 | 5.60 | 12.33 |
| $S_2F_4$ | 2.50 | 7.83 | 9.20 | 8.60 | 13.50 |
| $S_3F_1$ | 1.82 | 5.33 | 5.27 | 6.20 | 9.75 |
| $S_3F_2$ | 1.89 | 5.58 | 5.50 | 6.35 | 11.75 |
| $S_3F_3$ | 2.22 | 6.19 | 6.60 | 6.60 | 12.00 |
| $S_3F_4$ | 2.22 | 6.25 | 7.20 | 6.80 | 12.00 |
| SE (m) ± | 0.15 | 0.17 | 0.29 | 0.24 | 0.46 |
| CD at 5% | 0.43 | 0.51 | 0.85 | 0.71 | 1.34 |

significantly maximum root length and root girth was noticed with the application 6 t FYM ha$^{-1}$ at all the growth periods (24, 30 and 36 months) under study.The interaction effect was found to be significant at all the growth periods. The plant spacing of 100 x 150 cm with the application of 6 t FYM ha$^{-1}$ (S1xF4) recorded significantly maximum root length and root girth, except root length recorded at 30$^{th}$ months growth period It was significantly highest under plant spacing of 100 x 50 cm and 6 t FYM ha$^{-1}$ (S3xF4).

**Table 3 (a). Relative root length and girth of completely uprooted plants of Bilva/Bael (*Aegle marmelos*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | |
|---|---|---|---|---|
| | 12 | 18 | 12 | 18 |
| **Plant spacing (cm)** | **Root length (cm)** | **Root girth (cm)** | | |
| $S_1$ - (100 X 150 ) | 34.44 | 108.23 | 0.96 | 2.87 |
| $S_2$ - (100 X 100 ) | 33.40 | 83.88 | 0.94 | 2.75 |
| $S_3$ - (100 X 50 ) | 29.84 | 79.49 | 0.94 | 2.33 |
| SE (m) ± | 0.57 | 0.87 | 0.01 | 0.02 |
| CD at 5% | 1.66 | 2.56 | 0.02 | 0.05 |
| **FYM levels (t ha$^{-1}$)** | | | | |
| $F_1$ - 0.0 | 27.28 | 79.67 | 0.92 | 2.53 |
| $F_2$ - 2.0 | 32.21 | 91.61 | 0.95 | 2.57 |
| $F_3$ - 4.0 | 34.46 | 94.92 | 0.96 | 2.77 |
| $F_4$ - 6.0 | 36.28 | 95.86 | 0.95 | 2.72 |
| SE (m) ± | 0.65 | 1.01 | 0.01 | 0.02 |
| CD a 5% | 1.92 | 2.95 | 0.03 | 0.06 |
| **Interaction S x F** | | | | |
| $S_1F_1$ | 31.58 | 85.67 | 0.93 | 2.70 |
| $S_1F_2$ | 32.50 | 111.50 | 0.95 | 2.78 |
| $S_1F_3$ | 34.00 | 118.75 | 0.97 | 2.98 |
| $S_1F_4$ | 39.67 | 117.00 | 0.97 | 3.03 |
| $S_2F_1$ | 29.60 | 76.83 | 0.92 | 2.55 |
| $S_2F_2$ | 32.33 | 83.50 | 0.95 | 2.58 |
| $S_2F_3$ | 35.67 | 86.00 | 0.95 | 2.93 |
| $S_2F_4$ | 36.00 | 89.17 | 0.95 | 2.92 |
| $S_3F_1$ | 20.67 | 78.50 | 0.92 | 2.34 |
| $S_3F_2$ | 31.80 | 79.82 | 0.94 | 2.35 |
| $S_3F_3$ | 33.70 | 80.00 | 0.95 | 2.39 |
| $S_3F_4$ | 33.18 | 81.42 | 0.94 | 2.22 |
| SE (m) ± | 1.13 | 1.74 | 0.02 | 0.03 |
| CD at 5% | 3.32 | 5.12 | 0.05 | 0.11 |

**Root yield**

The data presented inTable 4 (a) revealed that the dry root yield of completely uprooted plants of Bael at 12 and 18 months growth periods was found to increase markedly with each growth period. The root yield was in the range of 0.52-1.29 q ha$^{-1}$ at 12 months and 6.65-16.81 q ha$^{-1}$ at 18 months growth period. Further, it was noticed that significantly highest root yield at 12 and 18 months growth periods was recorded with the closer plant spacing of 100 x 50 cm.

Application of FYM at various levels significantly influenced the dry root yield and significantly maximum root yield was noticed with the application 4 t FYM ha$^{-1}$, at all the growth period, however it was at par with the application 6 t FYM ha$^{-1}$. The interaction effect

**Table 3 (b) Lateral root length and girth of Bilva/Bael (*Aegle marmelos*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | | | |
|---|---|---|---|---|---|---|
| | 24 | 30 | 36 | 24 | 30 | 36 |
| **Spacing (cm)** | | **Root length (cm)** | | | **Root girth (cm)** | |
| S1 - (100 X 150 ) | 66.85 | 70.00 | 79.31 | 0.71 | 0.74 | 0.90 |
| S2 - (100 X 100 ) | 57.99 | 65.48 | 75.35 | 0.69 | 0.69 | 0.77 |
| S3 - (100 X 50 ) | 55.39 | 65.72 | 70.70 | 0.66 | 0.68 | 0.75 |
| SE (m) ± | 1.30 | 1.27 | 1.33 | 0.01 | 0.01 | 0.01 |
| CD 5% | 3.82 | 3.73 | 3.89 | 0.02 | 0.03 | 0.03 |
| **FYM levels (t $ha^{-1}$)** | | | | | | |
| F 1 - 0.0 | 51.01 | 58.58 | 62.26 | 0.61 | 0.65 | 0.69 |
| F 2 - 2.0 | 59.38 | 64.21 | 71.74 | 0.67 | 0.66 | 0.78 |
| F 3 - 4.0 | 62.41 | 69.33 | 81.08 | 0.73 | 0.76 | 0.86 |
| F 4 - 6.0 | 67.51 | 76.15 | 85.40 | 0.74 | 0.75 | 0.89 |
| SE (m) ± | 2.60 | 1.47 | 1.53 | 0.01 | 0.01 | 0.01 |
| CD at 5% | 7.64 | 4.31 | 4.49 | 0.02 | 0.04 | 0.03 |
| **Interaction S x F** | | | | | | |
| S1F1 | 54.75 | 59.50 | 67.50 | 0.65 | 0.68 | 0.70 |
| S1F2 | 62.63 | 71.50 | 77.25 | 0.59 | 0.70 | 0.90 |
| S1F3 | 73.75 | 73.13 | 86.00 | 0.74 | 0.78 | 1.00 |
| S1F4 | 73.25 | 75.88 | 86.50 | 0.74 | 0.80 | 1.00 |
| S2F1 | 45.09 | 60.42 | 63.58 | 0.63 | 0.62 | 0.68 |
| S2F2 | 55.30 | 63.83 | 70.83 | 0.68 | 0.68 | 0.72 |
| S2F3 | 59.30 | 64.17 | 81.75 | 0.72 | 0.75 | 0.80 |
| S2F4 | 72.27 | 73.50 | 85.75 | 0.74 | 0.76 | 0.87 |
| S3F1 | 53.20 | 55.82 | 55.71 | 0.54 | 0.64 | 0.70 |
| S3F2 | 57.20 | 57.30 | 67.13 | 0.64 | 0.65 | 0.71 |
| S3F3 | 54.17 | 70.70 | 75.50 | 0.73 | 0.74 | 0.78 |
| S3F4 | 57.00 | **79.06** | 84.45 | 0.73 | 0.70 | 0.80 |
| SE (m) ± | 2.60 | 2.54 | 2.65 | 0.02 | 0.03 | 0.02 |
| CD 5% | 7.64 | 7.46 | 7.77 | 0.05 | 0.08 | 0.06 |

was found to be significant at all the growth periods. The plant spacing of 100 x 50 cm with the application of 4 and 6 t FYM per hectare ($S_3xF_3$ and $S_3xF_4$) recorded significantly maximum dry root yield at all the growth periods (12 and 18 months).

During the growth periods of 24, 30 and 36 months only lateral roots were harvested and the data generated on the lateral root yield is presented in Table 4(b). The lateral root yield was also successively found to increase with each growth period. The root yield was in the range of 4.67-14.65 q $ha^{-1}$ at 24 months, 4.77-14.81 q $ha^{-1}$ at 30 months and 7.94-36.41 q $ha^{-1}$ at 36 months growth period. Further, it was noticed that significantly highest root yield was recorded with the closer plant spacing of 100 x 50 cm.

Application of FYM at various levels significantly influenced the root yield and significantly highest root yield was noticed with the application 6 t FYM ha$^{-1}$ at all the growth periods (24, 30 and 36 months) under study. The interaction effect was also found to be significant at all the growth periods. The plant spacing of 100 x 150 cm with the application of 6 t FYM ha$^{-1}$ ($S_1xF_4$) recorded significantly highest root yield at 24, 30 and 36 months growth periods.

**Table- 4 (a) Relative dry root yield of completely uprooted plants of Bilva/Bael (*Aegle marmelos*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | |
|---|---|---|---|---|
| | **12** | **18** | **12** | **18** |
| **Spacing (cm)** | **Dry root yield (g plant$^{-1}$)** | | **Dry root yield (q ha$^{-1}$)** | |
| $S_1$ - (100 X 150) | 8.85 | 149.45 | 0.59 | 9.97 |
| $S_2$ - (100 X 100) | 6.84 | 109.45 | 0.68 | 10.96 |
| $S_3$ - (100 X 50) | 6.14 | 74.20 | 1.23 | 14.85 |
| SE (m)± | 0.28 | 1.51 | 0.04 | 0.15 |
| CD at 5% | 0.82 | 4.44 | 0.10 | 0.44 |
| **FYM levels (t ha$^{-1}$)** | | | | |
| $F_1$ - 0.0 | 6.49 | 89.67 | 0.75 | 10.08 |
| $F_2$ - 2.0 | 7.37 | 101.43 | 0.84 | 10.91 |
| $F_3$ - 4.0 | 7.60 | 127.60 | 0.87 | 13.51 |
| $F_4$ - 6.0 | 7.66 | 125.43 | 0.88 | 13.20 |
| SE (m)± | 0.32 | 1.75 | 0.04 | 0.17 |
| CD at 5% | 0.95 | 5.13 | 0.12 | 0.50 |
| **Interaction S x F** | | | | |
| $S_1F_1$ | 7.75 | 99.70 | 0.52 | 6.65 |
| $S_1F_2$ | 9.00 | 132.50 | 0.60 | 8.84 |
| $S_1F_3$ | 9.33 | 185.80 | 0.62 | 12.40 |
| $S_1F_4$ | 9.33 | 179.80 | 0.62 | 12.00 |
| $S_2F_1$ | 6.00 | 102.80 | 0.60 | 10.29 |
| $S_2F_2$ | 7.00 | 104.80 | 0.70 | 10.49 |
| $S_2F_3$ | 7.17 | 113.00 | 0.72 | 11.31 |
| $S_2F_4$ | 7.17 | 117.20 | 0.72 | 11.73 |
| $S_3F_1$ | 5.71 | 66.50 | 1.14 | 13.31 |
| $S_3F_2$ | 6.10 | 67.00 | 1.22 | 13.41 |
| $S_3F_3$ | 6.30 | 84.00 | 1.26 | 16.81 |
| $S_3F_4$ | 6.47 | 79.30 | 1.29 | 15.87 |
| SE (m)± | 0.56 | 3.03 | 0.07 | 0.30 |
| CD at 5% | 1.64 | 8.88 | 0.21 | 0.87 |

**Table 4 (b) : Relative lateral dry root yield of Bilva/Bael (*Aegle marmelos*) as influenced by plant spacing and FYM levels.**

| Treatments | Growth Period (Months) | | | | | |
|---|---|---|---|---|---|---|
| | **24** | **30** | **36** | **24** | **30** | **36** |
| **Spacing (cm)** | | **Dry root yield (g plant$^{-1}$)** | | **Dry root yield (q ha$^{-1}$)** | | |
| S1 - (100 X 150 ) | 82.44 | 99.25 | 141.41 | 5.50 | 6.62 | 9.44 |
| S2 - (100 X 100 ) | 75.65 | 71.38 | 133.75 | 7.57 | 7.15 | 13.39 |
| S3 - (100 X 50 ) | 47.01 | 58.56 | 128.58 | 9.41 | 11.72 | 25.74 |
| SE (m) ± | 1.85 | 1.67 | 2.11 | 0.28 | 0.22 | 0.29 |
| CD at 5% | 5.42 | 4.91 | 6.20 | 0.83 | 0.64 | 0.86 |
| **FYM levels (t ha$^{-1}$)** | | | | | | |
| F 1 - 0.0 | 52.52 | 57.07 | 105.91 | 5.47 | 6.37 | 12.00 |
| F 2 - 2.0 | 59.22 | 66.28 | 118.83 | 6.19 | 7.48 | 14.25 |
| F 3 - 4.0 | 74.22 | 84.89 | 138.35 | 8.20 | 9.50 | 16.86 |
| F 4 - 6.0 | 87.51 | 97.33 | 175.43 | 10.11 | 10.64 | 21.63 |
| SE (m) ± | 2.14 | 1.93 | 2.44 | 0.33 | 0.25 | 0.34 |
| CD at 5% | 6.26 | 5.67 | 7.16 | 0.96 | 0.74 | 0.99 |
| **Interaction S x F** | | | | | | |
| S1F1 | 70.00 | 71.50 | 119.00 | 4.67 | 4.77 | 7.94 |
| S1F2 | 72.50 | 76.25 | 123.50 | 4.84 | 5.09 | 8.24 |
| S1F3 | 87.75 | 114.25 | 143.75 | 5.85 | 7.62 | 9.59 |
| S1F4 | 98.00 | 135.00 | 179.40 | 6.54 | 9.01 | 11.97 |
| S2F1 | 55.60 | 56.17 | 117.00 | 5.56 | 5.62 | 11.71 |
| S2F2 | 72.25 | 72.00 | 120.00 | 7.33 | 7.21 | 12.01 |
| S2F3 | 82.40 | 72.33 | 133.00 | 8.25 | 7.24 | 13.31 |
| S2F4 | 91.33 | 85.00 | 165.00 | 9.14 | 8.51 | 16.51 |
| S3F1 | 30.45 | 43.55 | 81.73 | 6.09 | 8.72 | 16.36 |
| S3F2 | 31.90 | 50.60 | 112.38 | 6.39 | 10.13 | 22.49 |
| S3F3 | 52.50 | 68.10 | 138.30 | 10.51 | 13.63 | 27.68 |
| S3F4 | 73.20 | 76.00 | 181.90 | 14.65 | 14.81 | 36.41 |
| SE (m) ± | 3.70 | 3.35 | 4.23 | 0.57 | 0.44 | 0.59 |
| CD at 5% | 10.85 | 9.82 | 12.41 | 1.67 | 1.28 | 1.72 |

**Physicochemical analysis of roots of Bilva/Bael (*Aegle marmelos*) as influenced by plant spacing and FYM levels.**

The data on physico and phyto-chemical parameters of roots of Bilva/Bael (*Aegle marmelos*) are presented in Table 5-8.

The physico and phyto-chemical analysis of composite sample of 6 months age roots of Bilva/Bael (*Aegle marmelos*) was done and the data is presented in Table-5.The WSE and ASE values were in the range of 15.97-21.77 per cent and 7.12-8.38 per cent, respectively. Total flavonoides (2.6%), Alkaloids (1.24%), Phenols (0.55%) and Glycosides (1.97%) were also found in the roots. The data (Table19) on water soluble extractive values revealed that the various plant spacing had influenced the WSE and highest values of WSE in the roots harvested at 12-24 months growth period were noticed with the wider spacing i.e. planting at 100 x 150 cm. No consistent data was observed due to the manurial treatments i.e. application of different levels of Farm Yard Manure under various plant spacing On the basis of general mean the WSE values were in the range of 10.62-18.05 per cent in the roots harvested from 12th months onwards up to 36th months at an interval of 6 months growth period. Further, it was observed that the WSE values (18.05%) was highest in the roots harvested at 36th months (i.e. June, 2011) followed by WSE (17.21%) recorded at 12th months (i.e. June, 2009) and WSE (15.10%) observed at 24th months (i.e. June, 2010). Comparatively lowest WSE values were noticed in the roots harvested at 30th months (December, 2010), followed by 18th months (December, 2009).

The data on alcohol soluble extractive values revealed that the various plant spacing and the manurial treatments i.e. application of different levels of Farm Yard Manure did not influence the ASE values in the roots of Bilva. On the basis of general mean the ASE values were in the range of 5.22-11.41per cent in the roots harvested from 12th months onwards up to 36th months at an interval of 6 months growth period. Further, it was observed that the ASE values (11.41%) was highest in the roots harvested at 24th months (i.e. June, 2010) followed by ASE (9.91%) recorded at 36th months (i.e. June, 2011) and ASE (9.71%) observed at 12th months (i.e. June,2009). Comparatively lowest ASE values (5.22%) were noticed in the roots harvested at 18th months (December, 2009), followed by 30th months (December, 2010).

On the basis of general mean the total ash values were in the range of 2.96-5.82 per cent and acid insoluble ash values were in the range of 0.74-2.51per cent in the roots harvested from 12th months onwards up to 36th months at an interval of 6 months growth period (Table7).

As the results obtained on physico-chemical constituents were not consistent with the manurial treatments i.e. application of different levels of FYM, the composite samples for each plant spacing(i.e.$S_1$,$S_2$ and $S_3$) with FYM @ 2 t FYM $ha^{-1}$ were analysed for phyto-chemical constituents .The results obtained are presented in Table 8.

The total flavonoids values were in the range of 2.30-3.78 per cent and Alkaloid values were in the range of 1.60-5.22 per cent. Further, it was notices that these constituents found to increase with the age and highest value were recorded with the roots harvested at 36th months growth period. The Phenols content was found in the range of 0.42-0.90 per cent and Glycosides content was noticed in the range of 1.60-2.58 per cent in the roots harvested from 18th months onwards up to 36th months at an interval of 6 months growth period.

**Table: 5 Physico and Phyto-chemical analysis of 6-month-old root sample of Bilva/ Bael (*Aegle marmelos*)**

| Treatments | WSE, % | ASE, % | TA, % | AIA, % |
|---|---|---|---|---|
| Sample-1 | 21.77 | 8.38 | 5.43 | 1.42 |
| Sample-2 | 17.03 | 8.36 | 5.05 | 0.63 |
| Sample-3 | 17.80 | 8.05 | 5.17 | 0.89 |
| Sample-4 | 15.97 | 8.05 | 5.16 | 0.72 |
| Sample-5 | 16.51 | 7.65 | 4.99 | 0.50 |
| Sample-6 | 16.78 | 7.12 | 4.73 | 0.41 |
| **Mean** | **17.64** | **7.94** | **5.09** | **0.76** |
| | | **Phyto-chemicals** | | |
| | **Total Flavonoids (%)** | **Alkaloids (%)** | **Phenols (%)** | **Glycosides (%)** |
| **Composite sample** | 2.6 | 1.24 | 0.55 | 1.97 |

**Table-6 Water and Alcohol Soluble Extractive values of Bilva/Bael (*Aegle marmelos*) roots as influenced by plant spacing and FYM levels.**

| **Treatments combinations** | **Growth Period (Months)** | | | | |
|---|---|---|---|---|---|
| **Plant spacing x FYM levels** | **12** | **18** | **24** | **30** | **36** |
| **$S_1$ 100 x 150 cm** | | | **Water Soluble Extractive (%)** | | |
| $F_1$ 0.0 t FYM $ha^{-1}$ | 18.62 | 16.45 | 13.44 | 12.27 | 17.70 |
| $F_2$ 2.0 t FYM $ha^{-1}$ | 19.21 | 16.65 | 17.44 | 10.08 | 19.79 |
| $F_3$ 4.0 t FYM $ha^{-1}$ | 20.40 | 16.36 | 12.76 | 10.96 | 18.35 |
| $F_4$ 6.0 t FYM $ha^{-1}$ | 16.76 | 14.56 | 17.72 | 11.36 | 16.15 |
| **Mean** | **18.75** | **16.01** | **15.34** | **11.17** | **18.00** |
| **$S_2$ 100 x 100 cm** | | | | | |
| $F_1$ 0.0 t FYM $ha^{-1}$ | 17.48 | 19.78 | 16.54 | 7.44 | 14.60 |
| $F_2$ 2.0 t FYM $ha^{-1}$ | 19.35 | 19.31 | 16.30 | 10.68 | 19.60 |
| $F_3$ 4.0 t FYM $ha^{-1}$ | 17.04 | 11.91 | 19.44 | 7.76 | 19.50 |
| $F_4$ 6.0 t FYM $ha^{-1}$ | 14.76 | 10.02 | 14.46 | 12.13 | 16.15 |
| **Mean** | **17.16** | **15.26** | **16.68** | **9.50** | **17.46** |
| **$S_3$ 100 x 50 cm** | | | | | |
| $F_1$ 0.0 t FYM $ha^{-1}$ | 14.90 | 10.07 | 12.68 | 19.80 | 22.42 |
| $F_2$ 2.0 t FYM $ha^{-1}$ | 14.39 | 8.85 | 10.56 | 7.58 | 16.95 |
| $F_3$ 4.0 t FYM $ha^{-1}$ | 17.12 | 12.50 | 16.28 | 10.13 | 17.80 |
| $F_4$ 6.0 t FYM $ha^{-1}$ | 16.50 | 10.39 | 13.56 | 7.28 | 17.65 |
| **Mean** | **15.73** | **10.45** | **13.27** | **11.20** | **18.70** |
| **General Mean** | **17.21** | **13.90** | **15.10** | **10.62** | **18.05** |
| | | | **Alcohol Soluble Extractive (%)** | | |
| **$S_1$ 100 x 150 cm** | | | | | |
| $F_1$ 0.0 t FYM $ha^{-1}$ | 10.05 | 5.37 | 8.92 | 5.24 | 8.00 |
| $F_2$ 2.0 t FYM $ha^{-1}$ | 8.13 | 4.71 | 11.08 | 5.48 | 8.30 |
| $F_3$ 4.0 t FYM $ha^{-1}$ | 10.22 | 5.01 | 12.12 | 5.38 | 10.46 |
| $F_4$ 6.0 t FYM $ha^{-1}$ | 7.40 | 5.86 | 14.52 | 5.17 | 9.40 |
| **Mean** | **8.95** | **5.24** | **11.66** | **5.31** | **9.04** |
| **$S_2$ 100 x 100 cm** | | | | | |
| $F_1$ 0.0 t FYM $ha^{-1}$ | 9.21 | 5.88 | 13.52 | 5.77 | 10.40 |
| $F_2$ 2.0 t FYM $ha^{-1}$ | 10.17 | 5.30 | 13.70 | 6.58 | 11.11 |
| $F_3$ 4.0 t FYM $ha^{-1}$ | 9.43 | 6.42 | 13.56 | 6.16 | 11.36 |
| $F_4$ 6.0 t FYM $ha^{-1}$ | 9.49 | 5.44 | 10.60 | 6.17 | 12.80 |
| **Mean** | **9.58** | **5.76** | **12.85** | **6.17** | **11.42** |
| **$S_3$ 100 x 50 cm** | | | | | |
| $F_1$ 0.0 t FYM $ha^{-1}$ | 10.87 | 4.91 | 8.22 | 6.28 | 9.30 |
| $F_2$ 2.0 t FYM $ha^{-1}$ | 10.79 | 4.82 | 7.42 | 6.18 | 9.72 |
| $F_3$ 4.0 t FYM $ha^{-1}$ | 10.37 | 4.69 | 12.68 | 5.89 | 7.30 |
| $F_4$ 6.0 t FYM $ha^{-1}$ | 10.46 | 4.23 | 10.56 | 5.32 | 10.73 |
| **Mean** | **10.62** | **4.66** | **9.72** | **5.92** | **9.26** |
| **General Mean** | **9.71** | **5.22** | **11.41** | **5.80** | **9.91** |

**Table 7 : Total ash and Acid insoluble ash of Bilva/Bael (*Aegle marmelos*) roots as influenced by plant spacing and FYM levels.**

| Treatments combinations | Growth Period (Months) | | | | |
|---|---|---|---|---|---|
| Plant spacing x FYM levels | 12 | 18 | 24 | 30 | 36 |
| **$S_1$ 100 x 150 cm** | | | **Total ash(%)** | | |
| $F_1$ 0.0 t FYM $ha^{-1}$ | 6.31 | 2.90 | 2.99 | 4.65 | 5.64 |
| $F_2$ 2.0 t FYM $ha^{-1}$ | 4.93 | 2.64 | 9.23 | 4.72 | 5.41 |
| $F_3$ 4.0 t FYM $ha^{-1}$ | 6.31 | 2.81 | 4.95 | 4.37 | 6.02 |
| $F_4$ 6.0 t FYM $ha^{-1}$ | 5.51 | 3.16 | 1.76 | 4.04 | 6.17 |
| **Mean** | **5.77** | **2.88** | **4.73** | **4.45** | **5.81** |
| **$S_2$ 100 x 100 cm** | | | | | |
| $F_1$ 0.0 t FYM $ha^{-1}$ | 5.36 | 2.57 | 4.82 | 3.80 | 6.35 |
| $F_2$ 2.0 t FYM $ha^{-1}$ | 4.77 | 2.74 | 6.24 | 3.00 | 5.91 |
| $F_3$ 4.0 t FYM $ha^{-1}$ | 5.05 | 3.00 | 3.91 | 4.37 | 5.73 |
| $F_4$ 6.0 t FYM $ha^{-1}$ | 4.64 | 2.85 | 4.17 | 4.09 | 5.65 |
| **Mean** | **4.96** | **2.79** | **4.79** | **3.82** | **5.91** |
| **$S_3$ 100 x 50 cm** | | | | | |
| $F_1$ 0.0 t FYM $ha^{-1}$ | 6.75 | 3.26 | 3.83 | 4.89 | 6.20 |
| $F_2$ 2.0 t FYM $ha^{-1}$ | 6.41 | 3.75 | 3.77 | 3.60 | 5.42 |
| $F_3$ 4.0 t FYM $ha^{-1}$ | 4.86 | 2.96 | 3.81 | 4.79 | 5.77 |
| $F_4$ 6.0 t FYM $ha^{-1}$ | 6.31 | 2.90 | 3.74 | 4.20 | 5.57 |
| **Mean** | **6.08** | **3.22** | **3.79** | **4.37** | **5.74** |
| **General Mean** | **5.60** | **2.96** | **4.43** | **4.21** | **5.82** |
| | | | **Acid insoluble ash (%)** | | |
| **$S_1$ 100 x 150 cm** | | | | | |
| $F_1$ 0.0 t FYM $ha^{-1}$ | 2.99 | 0.62 | 0.30 | 0.90 | 3.60 |
| $F_2$ 2.0 t FYM $ha^{-1}$ | 1.91 | 0.65 | 6.15 | 0.60 | 2.09 |
| $F_3$ 4.0 t FYM $ha^{-1}$ | 3.08 | 0.66 | 0.98 | 0.55 | 2.77 |
| $F_4$ 6.0 t FYM $ha^{-1}$ | 2.52 | 0.84 | 0.42 | 1.35 | 2.95 |
| **Mean** | **2.63** | **0.69** | **1.96** | **0.85** | **2.85** |
| **$S_2$ 100 x 100 cm** | | | | | |
| $F_1$ 0.0 t FYM $ha^{-1}$ | 2.04 | 0.54 | 1.50 | 0.90 | 3.32 |
| $F_2$ 2.0 t FYM $ha^{-1}$ | 1.79 | 0.49 | 1.73 | 0.55 | 2.31 |
| $F_3$ 4.0 t FYM $ha^{-1}$ | 1.81 | 0.82 | 0.81 | 0.70 | 2.22 |
| $F_4$ 6.0 t FYM $ha^{-1}$ | 1.85 | 0.92 | 0.85 | 0.90 | 2.35 |
| **Mean** | **1.87** | **0.69** | **1.22** | **0.76** | **2.55** |
| **$S_3$ 100 x 50 cm** | | | | | |
| $F_1$ 0.0 t FYM $ha^{-1}$ | 3.03 | 1.03 | 1.00 | 0.50 | 2.30 |
| $F_2$ 2.0 t FYM $ha^{-1}$ | 2.45 | 0.90 | 0.94 | 0.80 | 2.14 |
| $F_3$ 4.0 t FYM $ha^{-1}$ | 1.5 | 0.87 | 0.92 | 0.70 | 2.25 |
| $F_4$ 6.0 t FYM $ha^{-1}$ | 2.29 | 0.71 | 0.78 | 0.50 | 1.88 |
| **Mean** | **2.32** | **0.88** | **0.91** | **0.63** | **2.14** |
| **General Mean** | **2.27** | **0.75** | **1.36** | **0.74** | **2.51** |

**Table 8 : Total flavonoids, Alkaloid, Phenols and Glycosides in Bilva/Bael (*Aegle marmelos*) roots as influenced by different plant spacing.**

| Treatment combinations | Growth Period (Months) | | | | |
|---|---|---|---|---|---|
| | 12 | 18 | 24 | 30 | 36 |
| **Plant spacing x FYM levels** | | | **Total Flavonoids (%)** | | |
| **$S_1$ 100 x 150 cm x**F 2 2.0 t FYM $ha^{-1}$ | ND | 3.10 | 2.12 | 4.14 | 3.05 |
| **$S_2$ 100 x 100 cm x**F 2 2.0 t FYM $ha^{-1}$ | ND | 2.00 | 2.20 | 3.37 | 4.25 |
| **$S_3$ 100 x 50 cm x**F 2 2.0 t FYM $ha^{-1}$ | ND | 1.80 | 2.49 | 2.90 | 4.05 |
| **Mean** | | **2.30** | **2.27** | **3.47** | **3.78** |
| | | | **Alkaloid (%)** | | |
| **$S_1$ 100 x 150 cm x**F 2 2.0 t FYM $ha^{-1}$ | ND | 2.00 | 2.45 | 3.46 | **5.54** |
| **$S_2$ 100 x 100 cm x**F 2 2.0 t FYM $ha^{-1}$ | ND | 1.00 | 2.85 | 3.13 | 5.26 |
| **$S_3$ 100 x 50 cm x**F 2 2.0 t FYM $ha^{-1}$ | ND | 1.80 | 0.58 | **4.76** | 4.87 |
| **Mean** | | **1.60** | **1.96** | **3.77** | **5.22** |
| | | | **Phenols (%)** | | |
| **$S_1$ 100 x 150 cm x**F 2 2.0 t FYM $ha^{-1}$ | ND | 0.50 | 0.56 | 0.41 | 0.52 |
| **$S_2$ 100 x 100 cm x**F 2 2.0 t FYM $ha^{-1}$ | ND | 0.41 | 0.56 | 0.41 | 0.56 |
| **$S_3$ 100 x 50 cm x**F 2 2.0 t FYM $ha^{-1}$ | ND | **1.80** | 0.35 | 0.43 | 0.52 |
| **Mean** | | **0.90** | **0.49** | **0.42** | **0.53** |
| | | | **Glycosides (%)** | | |
| **$S_1$ 100 x 150 cm x**F 2 2.0 t FYM $ha^{-1}$ | ND | 2.00 | 2.80 | 2.33 | 1.46 |
| **$S_2$ 100 x 100 cm x**F 2 2.0 t FYM $ha^{-1}$ | ND | 1.80 | 3.18 | **2.41** | 1.60 |
| **$S_3$ 100 x 50 cm x**F 2 2.0 t FYM $ha^{-1}$ | ND | 1.00 | 1.76 | 2.34 | 2.24 |
| **Mean** | | **1.60** | **2.58** | **2.36** | **1.77** |

The WSE values reported/observed in the roots of Bilva harvested at 18-24$^{th}$ months under the study conforms the accepted limits and is having higher relevance in context of Ayurvedic methods of drug usage as these values are indicative of phyto-constituents in a given quantity medicinal plant material (Padma, *et.al* 2010).

Further, it is observed that the values of these phyto-chemical constituents were maximum in the roots of the brihat-panchmoola species under study harvested at 18$^{th}$-24$^{th}$ months onwards. Phyto-chemicals, polyphenols are largely recognized as anti-inflammatory, antiviral, antimicrobial and antioxidant agent (Narayana, *et.al.,2001*). As such, phenolics and flavanoides constitute major group of compounds which act as primary antioxidants (Adesegun *et.al.*, 2009) are known to react with hydroxyl radicals (Hussain *et.al.*1987) super-oxide anion radicals (Afanaslev *et.al.,* 1989), lipid peroxiradicals (Torel *et.al.*,1986), protect DNA from oxidative damage inhibitory against tumor cells and possess anti-inflammatory and antimicrobial properties. Thus, the results of this study signify that the roots of Bilva/Bael (*Aegle marmelos*) at the age of 24 months growth period could be a source of natural antioxidant and anti-inflammatory drug.

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# Management of Pulse Beetle (*Callosobruchus chinensis* L.) in Stored Chickpea with Some Vegetable Oils

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## ABSTRACT

An experiment was conducted in laboratory of AICRP on PHET, Dr. PDKV, Akola(M.S) during 2015-16 to 2017-18 to find out effective, safer plant products as an alternative to synthetic insecticide and to evaluate eco-friendly and effective material against pulse beetle. Different vegetable oils as seed treatment with various doses were tested against pulse beetle in stored chickpea. Minimum per cent grain damage, minimum per cent grain weight loss in stored chickpea and maximum per cent mortality in bruchids was observed in grains treated with castor oil and groundnut oil @10 ml $kg^{-1}$ grain, 7.5 ml $kg^{-1}$ and 5 ml $kg^{-1}$ grain, respectively which were at par with each other. Minimum number of eggs $100^{-1}$ grains were recorded in the grain treated with ground nut oil @ 10 ml $kg^{-1}$ grain and castor oil @ 10 ml $kg^{-1}$ grain followed by groundnut oil and castor oil @ 0.5 and 7.5 ml $kg^{-1}$ grain treatments.

Chickpea is the most important pulse crops after dry bean and peas. India has a record of chickpea area and production of 3.55 million ha and 7.17 million tones respectively (Annon., 2017). Maharashtra is the largest producer of chickpea accounting 14.00 per cent of the total production followed by Madhya Pradesh (39%).

In India there are about 200 species of insect pests which cause damage to grains and grains products in storage. *Callosobruchus chinensis* is a major, economically important pest of all pulses and cause 40-50 per cent losses of pulses in storage (Ghosh *et al.,* 2003).

Heavy qualitative and quantitative losses occur due to the attack of pulse beetle (*C. chinensis* L.) on the stored chickpea grains and other stored grains such as beans, gram and lentil seeds in the developing countries. Invasion of this insect causes reduction in germination of grains, weight loss and lower market value (Raja and William, 2008; Patel, 2011; Sagheer *et al*., 2013; Islam *et al*., 2013 and Tefsu and Emana, 2013). Numerous control methods have been used for the control of *C. chinensis* including the use of larval parasitoids as biological control agent, changes in temperature of storage house, microwave energy use and chemical control.

Success achieved so far in making the stored products free from pests has been largely dependent on pesticides alone. Pesticides are the most powerful tool available for pest control. Despite these credentials, the long and indiscriminate use of pesticides has been found ecologically unsound. Insecticides were found to cause toxic effects on the produce intended for consumption, which forced a processor to look towards plants and plant products as protectants for stored products as an alternative to the highly persistent synthetic chemicals.

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There is a need to find some alternative procedure for the control of *C. chinensis*. These methods should be cheaper, safe to environment and human health and highly effective in use of alternative method found is the use of plant part and their products as repellent and deterrents (Sagheer *et al*., 2013; Khan *et al*., 2014 and Hasan *et al*., 2014).

Plant-derived materials are more readily biodegradable, relatively specific in the mode of action and easy to use (Das, 1986); they are environmentally safe, less hazardous, less expensive and readily available.

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Some are less toxic to mammals, may be more selective in action, and may retard the development of resistance. Their main advantage is that they may be easily and cheaply produced by farmers and small-scale industries as crude, or partially purified extracts.It was reported that when mixed with stored-grains, leaf, bark, seed powder, or oil extracts of plants reduce oviposition rate and suppress adult emergence of bruchids, and also reduced seed damage rate (Talukder and Howse, 1994 and Tapondjou *et. al.*, 2002). This article describes reasons to carry out an investigation for "Efficacy of vegetable oils against pulse beetle (*Callosobruchus.* spp) in stored chickpea".

## MATERIAL AND METHODS

An experiment was conducted in laboratory of AICRP on PHET, Dr. PDKV, Akola(M.S) during 2015-16 to 2017-18 in completely randomized design with sixteen treatments replicated thrice to find out effective, safer plant products as an alternative to synthetic insecticide and to evaluate eco-friendly and effective material against pulse beetle. Different vegetable oils as seed treatment with various doses were tested against pulse beetle in stored chickpea. Mass culture of *C. chinensis* L. was maintained in laboratory. Sample of 1000 g of seed was used for each treatment. The requisite quantity of each oil was used for treating the sample. Treated sample was shaken slowly so that grains get treated properly. A stock of chickpea treated with the oil was stored in perforated polythene bags. The observation on percent grain weight loss and per cent grain damage was recorded after 30, 60, 90, 120,150 and 180 days.

Separately, one hundred grams of chickpea was thoroughly mixed with the botanicals at @ given in table 1. Effect of these material was evaluated against bruchids in chickpea in a plastic container of 250 ml capacity. Randomly selected 20 bruchid adults were exposed to each concentration of main treatment. The no. of dead and morbid adult was counted at an interval of 48 hrs. and such observations were recorded for 12 days for actual

**Table 1. Effect of different vegetable oils on per cent grain damage of stored chickpea (3 years pooled data)**

| Tr.No. | Treatment | Dose ml kg$^{-1}$ | Per cent grain damage after | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 30 days | 60 days | 90 days | 120 days | 150 days | 180 days |
| 1 | Mustard oil | 5 | 1.17(1.14) | 3.17(1.71) | 4.33(2.19) | 6.0(2.87) | 10.83(3.35) | 14.33(3.84) |
| 2 | Mustard oil | 7.5 | 1.00(1.09) | 2.67(1.76) | 3.67(2.03) | 5.67(2.46) | 8.17(2.93) | 12.17(3.54) |
| 3 | Mustard oil | 10 | 0.83(1.05) | 2.17(1.60) | 3.33(1.95) | 4.5(2.22) | 7.002.72) | 11.33(3.43) |
| 4 | Ground nut oil | 5 | 0.0(0.71) | 0.67(1.00) | 0.83(1.05) | 1.00(1.09) | 2.0(1.52) | 3.33(1.92) |
| 5 | Ground nut oil | 7.5 | 0.0(0.71) | 0.33(0.85) | 0.67(1.00) | 1.00(1.09) | 1.67(1.43) | 2.67(1.77) |
| 6 | Ground nut oil | 10 | 0.0(0.71) | 0.0(0.71) | 0.50(0.94) | 0.83(1.05) | 0.83(1.05) | 1.33(1.26) |
| 7 | Castor oil | 5 | 0.0(0.71) | 0.0(0.71) | 0.0(0.71) | 0.0(0.71) | 1.00(1.17) | 1.33(1.61) |
| 8 | Castor oil | 7.5 | 0.0(0.71) | 0.0(0.71) | 0.0(0.71) | 0.0(0.71) | 0.67(1.02) | 0.67(1.05) |
| 9 | Castor oil | 10 | 0.0(0.71) | 0.0(0.71) | 0.0(0.71) | 0.0(0.71) | 0.0(0.71) | 0.33(0.88) |
| 10 | Coconut oil | 5 | 3.17(1.90) | 6.17(2.57) | 9.0(3.07) | 10.67(3.33) | 14.5(3.86) | 18.17(4.32) |
| 11 | Coconut oil | 7.5 | 2.83(1.80) | 5.17(2.37) | 7.33(2.79) | 9.33(3.13) | 11.83(3.50) | 15.33(3.97) |
| 12 | Coconut oil | 10 | 2.33(1.67) | 4.33(2.19) | 7.17(2.77) | 8.17(2.92) | 10.17(3.26) | 14.67(3.89) |
| 13 | Palm oil | 5 | 3.33(1.95) | 5.83(2.50) | 7.83(2.88) | 9.50(3.14) | 12.00(3.52) | 16.17(4.07) |
| 14 | Palm oil | 7.5 | 2.83(1.80) | 4.67(2.26) | 8.00(2.57) | 9.67(3.16) | 11.67(3.47) | 14.33(3.84) |
| 15 | Palm oil | 10 | 2.67(1.76) | 4.67(2.26) | 7.00(2.65) | 8.83(3.05) | 10.50(3.30) | 13.0(3.65) |
| 16 | Untreated control | - | 4.83(2.26) | 8.33(2.91) | 12.33(3.57) | 15.83(4.06) | 20.17(4.56) | 24.83(4.69) |
| | SE (m) ± | 0.14 | 0.14 | 0.19 | 0.22 | 0.26 | 0.31 | |
| | CD at 5% | 0.43 | 0.42 | 0.57 | 0.66 | 0.78 | 0.94 | |

Figures in parenthesis are Square root (X+0.5) transformed values effects of each treatment. Thus per cent mortality and per cent grain weight loss was also worked out. The data thus obtained was analyzed statistically in CRD.

## RESULTS AND DISCUSSION

### Per cent grain damage in stored chickpea

It is revealed from table 1 that significantly minimum (0.33%) grain damage in stored chickpea was observed in the treatment castor oil @10 ml $kg^{-1}$ grain which was found at par with castor oil @7.5 ml $kg^{-1}$ grain (0.67 %), castor oil @5.0 ml $kg^{-1}$ grain (1.33 %), groundnut oil @10 ml $kg^{-1}$ grain (1.33 %), groundnut oil @7.5 ml $kg^{-1}$ grain (2.67 %) and groundnut oil @5.0 ml kg grain (3.33 %). The next best treatment was palm oil @10ml $kg^{-1}$ grain (13.0 %). The maximum per cent grain damage was recorded in untreated control (24.83 %).

### Per cent grain weight loss in stored chickpea

It is revealed from Table 2 that the minimum (0.03 %) grain weight loss in stored chickpea was observed in the treatment castor oil @10 ml $kg^{-1}$ grain which was found at par with groundnut oil @10.0 ml $kg^{-1}$ grain(0.05 %), castor oil @7.5 ml $kg^{-1}$ grain (0.10 %), castor oil @5.0 ml $kg^{-1}$ grain (0.11 %), groundnut oil @7.5 ml kg grain (0.31 %), groundnut oil @5.0 ml $kg^{-1}$ grain (0.35 %). The next best treatment was palm oil @10 ml $kg^{-1}$ grain (1.0 %). The maximum per cent grain damage was recorded in untreated control (7.07 %).

### Per cent mortality of bruchids in stored chickpea

Maximum (25.0 %) mortality in bruchids in stored chickpea was observed in the treatment with castor oil @10 ml $kg^{-1}$ grain, groundnut oil @10 ml $kg^{-1}$ grain and groundnut oil @ 7.5 ml $kg^{-1}$ grain. These treatment were found at par with castor oil @7.5 ml $kg^{-1}$ grain, castor oil @5.0 ml $kg^{-1}$ grain, groundnut oil @7.5 ml $kg^{-1}$ grain and groundnut oil @5.0 ml $kg^{-1}$ grain ( Table 3.) .

Maximum no. of eggs (70.0 eggs)of bruchidswere recorded in untreated control (table 4).Minimum number (17.33) of eggs $100^{-1}$grains were recorded in the grain treated with ground nut oil @ 10ml $kg^{-1}$ grain which was at par with castor oil @ 10 ml $kg^{-1}$ grain (18.17 eggs $100^{-1}$

**Table 2. Effect of different vegetable oils on per cent grain weight loss of stored chickpea (3 years Pooled Data )**

| Tr.No. | Treatment | Dose ml $kg^{-1}$ | Per cent grain weight loss after | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 30 days | 60 days | 90 days | 120 days | 150 days | 180 days |
| 1 | Mustard oil | 5 | 0.08(0.76) | 0.28(0.88) | 0.40(0.95) | 0.57(1.02) | 1.01(1.22) | 1.63(1.44) |
| 2 | Mustard oil | 7.5 | 0.03(0.73) | 0.19(0.83) | 0.35(0.92) | 0.50(1.00) | 0.76(1.12) | 1.27(1.32) |
| 3 | Mustard oil | 10 | 0.02(0.72) | 0.17(0.81) | 0.24(0.86) | 0.34(0.94) | 0.55(1.02) | 1.10(1.25) |
| 4 | Ground nut oil | 5 | 0.00(0.71) | 0.03(0.73) | 0.05(0.74) | 0.08(0.79) | 0.21(0.83) | 0.35(0.90) |
| 5 | Ground nut oil | 7.5 | 0.00(0.71) | 0.02(0.72) | 0.03(0.73) | 0.07(0.75) | 0.16(0.80) | 0.31(0.88) |
| 6 | Ground nut oil | 10 | 0.00(0.71) | 0.0(0.71) | 0.00(0.71) | 0.0(0.71) | 0.03(0.73) | 0.05(0.74) |
| 7 | Castor oil | 5 | 0.00(0.71) | 0.00(0.71) | 0.00(0.71) | 0.00(0.71) | 0.03(0.73) | 0.11(0.78) |
| 8 | Castor oil | 7.5 | 0.00(0.71) | 0.00(0.71) | 0.00(0.71) | 0.00(0.71) | 0.03(0.73) | 0.10(0.77) |
| 9 | Castor oil | 10 | 0.00(0.71) | 0.00(0.71) | 0.00(0.71) | 0.00(0.71) | 0.03(0.73) | 0.03(0.73) |
| 10 | Coconut oil | 5 | 0.32(0.90) | 0.48(0.99) | 0.64(1.06) | 1.03(1.24) | 1.43(1.38) | 2.63(1.74) |
| 11 | Coconut oil | 7.5 | 0.24(0.86) | 0.36(0.93) | 0.59(1.04) | 0.90(1.19) | 1.25(1.32) | 1.92(1.53) |
| 12 | Coconut oil | 10 | 0.14(0.80) | 0.29(0.88) | 0.37(0.93) | 0.61(1.05) | 1.00(1.23) | 1.57(1.43) |
| 13 | Palm oil | 5 | 0.15(0.80) | 0.36(0.93) | 0.46(0.97) | 0.74(1.11) | 1.20(1.30) | 1.70(1.48) |
| 14 | Palm oil | 7.5 | 0.05(0.74) | 0.24(0.85) | 0.37(0.92) | 0.64(0.73) | 1.05(1.24) | 1.31(1.35) |
| 15 | Palm oil | 10 | 0.02(0.72) | 0.17(0.81) | 0.31(0.89) | 0.43(0.96) | 0.77(1.12) | 1.00(1.22) |
| 16 | Untreated control | - | 0.32(0.90) | 0.76(1.12) | 1.14(1.27) | 2.65(1.73) | 4.62(2.21) | 7.07(2.71) |
| | SE(M)± | | 0.01 | 0.01 | 0.01 | 0.021 | 0.07 | 0.10 |
| | CD at 5% | | 0.03 | 0.03 | 0.03 | 0.063 | 0.22 | 0.30 |

Figures in parenthesis are Square root (X+0.5) transformed values

**Table 3. Effect of different vegetable oils on per cent mortality of bruchids in stored chickpea ( 3 years Pooled Data)**

| Tr.No. | Treatment | Dose ml $kg^{-1}$ | Per cent mortality of bruchids after | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 2 days | 4 days | 6 days | 8 days | 10 days | 12 days |
| 1 | Mustard oil | 5 | 0.0 | 0.0(0.71) | 1.67(1.26) | 8.33(2.94) | 10.00(3.21) | 13.33(3.69) |
| 2 | Mustard oil | 7.5 | 0.0 | 1.67(1.26) | 2.50(1.40) | 10.83(3.36) | 14.17(3.80) | 17.5(4.22) |
| 3 | Mustard oil | 10 | 0.0 | 1.67(1.26) | 9.17(3.06) | 11.67(3.45) | 15.83(4.02) | 18.33(4.33) |
| 4 | Ground nut oil | 5 | 0.0 | 9.33(3.06) | 12.50(3.59) | 18.33(4.10) | 20.00(4.53) | 23.33(4.88) |
| 5 | Ground nut oi0l | 7.5 | 0.0 | 10.83(3.32) | 14.50(3.82) | 18.33(4.10) | 25.00(5.04) | 25.00(5.04) |
| 6 | Ground nut oil | 10 | 0.0 | 13.33(3.67) | 13.33(3.71) | 20.00(4.31) | 25.00(5.04) | 25.00(5.04) |
| 7 | Castor oil | 5 | 0.0 | 8.33(2.94) | 11.67(2.94) | 11.67(3.47) | 16.67(4.14) | 18.33(4.32) |
| 8 | Castor oil | 7.5 | 0.0 | 8.33(2.94) | 13.33(3.71) | 13.33(3.71) | 16.67(4.14) | 21.67(4.68) |
| 9 | Castor oil | 10 | 0.0 | 12.50(3.56) | 15.0(3.88) | 20.00(4.53) | 20.00(4.53) | 25.00(5.04) |
| 10 | Coconut oil | 5 | 0.0 | 1.67(1.25) | 3.33(1.55) | 5.00(2.07) | 7.50(2.79) | 9.17(3.09) |
| 11 | Coconut oil | 7.5 | 0.0 | 1.67(1.25) | 3.33(1.52) | 6.67(2.61) | 10.00(3.18) | 10.00(3.17) |
| 12 | Coconut oil | 10 | 0.0 | 3.33(1.55) | 6.67(2.31) | 9.17(3.01 | 11.67(3.47) | 11.67(3.47) |
| 13 | Palm oil | 5 | 0.0 | 0.0(0.71) | 1.67(1.26) | 3.33(1.80) | 5.0(2.10) | 7.50(2.79 |
| 14 | Palm oil | 7.5 | 0.0 | 1.67(1.26) | 3.33(1.55) | 5.0(2.10) | 9.17(2.01) | 10.83(3.32) |
| 15 | Palm oil | 10 | 0.0 | 1.67(1.26) | 3.33(1.55) | 7.50(2.79) | 9.17(2.76) | 14.17(3.69) |
| 16 | Untreated control | - | 0.0 | 0.0(0.71) | 0.0(0.71) | 0(0.71) | 1.67(1.26) | 3.33(1.80) |
| | SE(m)± | - | - | 0.23 | 0.21 | 0.22 | 0.32 | 0.31 |
| | CD at 5% | - | - | 0.69 | 0.63 | 0.66 | 0.96 | 0.93 |

Figures in parenthesis are Square root (X+0.5) transformed values

grains), groundnut oil @7.5 ml $kg^{-1}$ grain (23.33 eggs), castor oil @7.5 ml $kg^{-1}$ grain (24.83 eggs), groundnut oil @5.0 ml $kg^{-1}$ grain(27.33 eggs), castor oil @5.0 ml $kg^{-1}$ grain (27.67 eggs). The next best treatment was palm oil @10ml $kg^{-1}$ grain (33.67 eggs).

## CONCLUSION

Minimum per cent grain damage, minimum per cent weight loss, minimum number of eggs laid and minimum adult emergence recorded in the pulse grain treated with Castor oil 10 ml $kg^{-1}$ and Groundnut oil 10 ml $kg^{-1}$ pulse grain /stored chickpea and which were found on par with the lower doses of castor oil and groundnut oil 7.5 ml and 0.5ml $kg^{-1}$ pulse grain

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**Table 4. Effect of different vegetable oils on no. of eggs and adult of bruchids in stored chickpea( 3 year Pooled Data)**

| Tr.No. | Treatment | Dose ml $kg^{-1}$ | *C. chinensis* | | Cost of Treatment |
|---|---|---|---|---|---|
| | | | No. of eggs100 $grains^{-1}$ | No. of adult emerged | (Rs.) $Q^{-1}$ Pulse grain |
| 1 | Mustard oil | 5 | 39.50(6.29) | 28.33(5.33) | 65 |
| 2 | Mustard oil | 7.5 | 35.50(6.01) | 24.33(4.93) | 97.5 |
| 3 | Mustard oil | 10 | 29.17(5.39) | 20.83(4.60) | 130 |
| 4 | Ground nut oil | 5 | 27.33(5.18) | 12.33(3.35) | 54 |
| 5 | Ground nut oil | 7.5 | 23.33(4.84) | 9.17(2.92) | 81 |
| 6 | Ground nut oil | 10 | 17.33(4.19) | 8.17(2.77) | 108 |
| 7 | Castor oil | 5 | 27.67(5.25) | 6.73(2.65) | 70 |
| 8 | Castor oil | 7.5 | 24.83(4.97) | 4.75(2.25) | 105 |
| 9 | Castor oil | 10 | 18.17(4.28) | 3.87(2.07) | 140 |
| 10 | Coconut oil | 5 | 46.83(6.83) | 36.33(5.97) | 110 |
| 11 | Coconut oil | 7.5 | 42.00(6.51) | 32.33(5.63) | 165 |
| 12 | Coconut oil | 10 | 39.00(6.23) | 27.17(5.13) | 220 |
| 13 | Palm oil | 5 | 42.17(6.51) | 31.67(5.63) | 39 |
| 14 | Palm oil | 7.5 | 37.0(6.14) | 26.67(5.17) | 59 |
| 15 | Palm oil | 10 | 33.67(5.82) | 22.17(4.71) | 78 |
| 16 | Untreated control | - | 70.0(8.38) | 63.33(7.99) | |
| | SE (m) $\pm$ | 0.34 | 0.28 | | |
| | CD at 5% | 1.02 | 0.84 | | |

Figures in parenthesis are square root transformed values

**Market price :**Chickpea as on 2017-18= Rs.5000/q,

Musturd Oil= Rs.130 $kg^{-1}$ Groundnut Oil=Rs=108 $kg^{-1}$

Castor Oil=Rs.140 $kg^{-1}$ Coconut Oil = Rs.220,

Palm Oil = Rs. 78 $kg^{-1}$

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# Effect of Neem Leaf (*Azadirachta indica*) and Ginger Powder Supplementation on Feed Intake of Giriraj Poultry Birds

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## ABSTRACT

A study was conducted at Department of Animal Husbandry and Dairy Science, Dr. PDKV., Akola during 2017 to evaluate the effect of neem leaf powder (NLP ) and Ginger powder (GP) with sole and in combination for Giriraja Chicken breed with diet supplemented with $T_1$ (Control), $T_2$ (0.5% NLP), $T_3$ (1 % NLP), $T_4$(1% GP), $T_5$ (1.5% GP), $T_6$ (0.5% NLP +1% GP), $T_7$ (1% NLP + 1.5 % GP), $T_8$ (1% NLP + 1% GP) and $T_9$ (1% NLP + 1.5 % GP) in the diet. The average weekly feed consumption during 4th week under different treatments observed were $T_1$ (398.80), $T_2$ (385.80), $T_3$ (385.70), $T_4$(386.93), $T_5$ (381.13), $T_6$ (386.30), $T_7$ (381.0), $T_8$ (377.27) and $T_9$ (373.33) g/bird. This indicates that decreasing trend in feed consumption in sole supplementation and in combination group. It is concluded that, saving on feed requirement of birds by 32 per cent during rearing from day old to 7th week of age in spite of lower feed consumption more live body weight by 54 per cent at 7th week of rearing due to more body weight gain by 52 per cent.

The poultry production system have led a marked increase in production of poultry meat and eggs throughout the world (Armstrong, 1986) . It has triggered the discovery and wide spread use of number of "feed additives". The term feed additives is applied in a broad sense, to all products other than these commonly called feed stuffs which could be added to the ration with the purpose of obtaining some special effects. The main objective of adding feed additives is to boost animal performance by increasing their growth rate, better feed conversion efficiency, greater livability and lowered mortality in poultry birds. The production of healthy birds with quality meat and eggs without harmful residue within a short time interval is the major concern to modern poultry farmers. The use of synthetic drugs as antibiotics and growth promoters has high cost implication.

Sometimes, with attending adverse side effects on birds health if prolonged withdrawal period and increases risk of accumulation in tissues and eggs which could have harmful effect on human health (Jawad *et al.,* 2014). In view of this consumers of poultry product dwellers, demanding for drug reside free meat and eggs. This has triggered the search for alternatives means to produce birds at reduced cost using natural growth and health promoters.

Herbs and spices are most important parts of the human diet in addition to boosting flavor herb and spices are also known for their preservative and medicinal values (Punita Kumari *et.al.,*2014). The neem (*Azadiracta indica*) is a tropical evergreen tree native to Indo-Pak subcontinent (*Anonyms, 1985*). Presently neem trees can be neem growing successfully in about 72 countries worldwide (Girish and Shankara, 2008).Biologically active principles isolated from different parts of the plant include azadiractin, meliacin, gedunin, salanin, nimbin, valassin and many other derivatives of these principles. Miliacin forms the bitter principles of its leaves (Annonymous, 1912).

*Ginger* (*Zingiber officinale)* have been successfully used as supplement to enhance the health and performance of livestock particularly monogastric animals including poultry (Obun and Ayanwale, 2008). It has good source of dietary fiber has particularly no fat and cholesterol.

## MATERIAL AND METHODS

### Procurement of Neem tree leaves

The Neem tree leaves were collected from nearby campus of Department of Animal Husbandry and Dairy Science, Dr. PDKV., Akola. The collected fresh tree leaves were washed with water and clean from dust with the view to maintain hygienic condition.

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**Drying and preparation of Neem leaf powder**

The fresh clean, succulent green leaves of neem tree were put into the tray for drying and these fresh leaves were keep into the mechanical tray dryer machine for drying. The temperature for drying was maintained up to 40 $^0$C for 2-4 hours. The dried neem tree leaves were grind into fine powder at the laboratory .The powder was stored in air tight polythene bag with the aim to reduce the moisture and development of fungus during storage until use. The dried ginger was grind in mechanical grinder at Department of Agronomy laboratory into fine powder. This was stored in air tight polythene bags until use.

**Selection of Experimental chicks**

The 270 number of day old chicks of Giriraja Poultry birds were purchased from Government Hatchery

On arrival of chicks were weighted and distributed randomly into nine treatment groups viz $T_1$ (Control), $T_2$ (0.5% NLP), $T_3$ (1% NLP), $T_4$(1 % GP), $T_5$ (1.5%t GP), $T_6$ (0.5% NLP + 1% GP), $T_7$ (1% NLP + 1.5 % GP), $T_8$ (1% NLP + 1% GP) and $T_9$ (1 % NLP + 1.5 % GP) with 30 chicks in each group on nearly equal weight basis. The birds were randomly divided into three replicate group of each treatment and the chicks were housed in separate compartment. All the chicks were vaccinated as per the schedule carried out at Central Poultry Development Organization, Mumbai. The statistical method for data analysis used was CRD.

## RESULTS AND DISCUSSION

The feed consumption in last 7$^{th}$ week of the trial was 731.93 , 712.36, 712.30, 701.93, 702,50, 695.43, 688.83, 682.23 and 660.60 g bird$^{-1}$ under $T_1$, $T_2$, $T_3$, $T_4$, $T_5$ ,$T_6$, $T_7$, $T_8$ and T9 groups respectively. The present range of feed consumption (660 to 631 g bird$^{-1}$) gets confirmation from the results of Mali *et al* (2015) and Bajad *et al.,* (2017), they reported the consumption of Giriraja between 653 to 675, 675 to 678 and 672 g bird$^{-1}$, respectively. Thus, the results on feed consumption pattern of birds over 7$^{th}$ week trial clearly indicated that, there was consistency in lower intake of feed in birds with the supplementation of sole NLP and GP as well as their combinations at different levels in diet in reference to $T_1$ control birds. This means the herbal NLP and GP growth promoters did not help to improve the feed intake in birds. However, one has to assess this lower feed consumption in birds due to inclusion of NLP and GP growth promoters on the basis it's positive or negative influence on growth performance of birds.

The feed consumption recorded in treatment

**Table 1 : Effect of feeding Neem leaf powder (NLP), Ginger powder (GP) and their mixtures on weekly feed consumption of Giriraja birds**

| Treatment | Average weekly feed consumption g bird$^{-1}$ | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1$^{st}$ | 2$^{nd}$ | 3$^{rd}$ | 4$^{th}$ | 5$^{th}$ | 6$^{th}$ | 7$^{th}$ |
| $T_1$ - Control | 71.77$^a$ | 238.67$^a$ | 320.47$^a$ | 398.80$^a$ | 464.92$^a$ | 661.70$^a$ | 731.93$^a$ |
| $T_2$ - 0.5% NLP | 71.64$^a$ | 235.50$^a$ | 315.03$^b$ | 385.80$^b$ | 438050$^b$ | 645.40$^b$ | 712.37$^b$ |
| $T_3$ - 1% NLP | 71.49$^b$ | 233.17$^b$ | 313.08$^b$ | 385.70$^b$ | 436.57$^b$ | 655.73$^c$ | 712.30$^b$ |
| $T_4$ - 1 % GP | 71.37$^b$ | 233.33$^b$ | 313.33$^b$ | 386.93$^b$ | 428.17$^b$ | 619.50$^d$ | 701.93$^c$ |
| $T_5$ - 1.5%t GP | 71.41$^b$ | 233.90$^{ab}$ | 309.47$^c$ | 381.13$^c$ | 436.20$^b$ | 628.00$^e$ | 702.50$^c$ |
| $T_6$ - 0.5% NLP + 1% GP | 71.44$^b$ | 236.30$^a$ | 310.60$^C$ | 386.30$^b$ | 438.20$^b$ | 636.30$^f$ | 695.43$^d$ |
| $T_7$ - 1% NLP + 1.5 % GP | 71.41$^b$ | 230.43$^b$ | 309.40$^d$ | 381.00$^c$ | 427.63$^b$ | 622.30$^d$ | 688.83$^e$ |
| $T_8$ - 1% NLP + 1% GP | 71.59$^{ab}$ | 228.37$^b$ | 311.23$^c$ | 377.27$^d$ | 435.27$^b$ | 638.03$^f$ | 682.23$^f$ |
| $T_9$ - 1 % NLP + 1.5 % GP | 71.36$^b$ | 229.97$^b$ | 299.17$^d$ | 373.33$^e$ | 425.30$^b$ | 608.70$^g$ | 660.60$^g$ |
| SE (m) ± | 0.091 | 2.43 | 1.08 | 1.25 | 5.68 | 1.15 | 1.13 |
| CD at 5 % | 0.253 | 6.74 | 3.01 | 3.49 | 15.77 | 3.21 | 3.15 |

groups were significantly lower by 2.74 to 10.80 per cent than that of $T_1$ control group, as well as the feed intake of $T_9$ group was significantly lower by 7.83 per cent as compare to other treatment groups ($T_2$ to $T_8$). Similarly the feed intake of sole NLP ($T_2$ - $T_3$) supplementation groups were significantly higher than that of sole GP ($T_4$ - $T_5$) inclusion and its mixture with NLP ($T_6$, $T_7$ and $T_8$) groups.

Moreover, Herawati (2010) , Gbemiga *et. al.,* (2013) reported decrease in feed consumption due to addition of 1.5 per cent to 2 per cent ginger, 0.5 per cent NLP and Tulsi + Neem leaves in the diet of broilers, respectively. Rebh *et al* (2014) also noticed decrease in feed intake due to inclusion of 0.75 to 2.25 g $kg^{-1}$ of ginger root powder in diet wirh reference to control. But the differences were non-significant. These observations support the present trend on feed intake with inclusion of herbal growth promoters in the diet. On the contrary Ademola *et al* (2009) reported higher intake of feed in birds as a supplementation of 1 to 2 per cent ginger powder in diet, which does not agree with present results on Ginger supplementation to diet.

However, majority of the past workers like Doley *et al* (2009) , Zhang *et al.* (2009) , Elagib *et al.* (2013) , Obun *et al.* ( 2013) reported that supplementation of 0.25 per cent Ginger powder, 5 g $kg^{-1}$ feed Ginger powder, 2 per cent Ginger powder , 5 per cent to 15 per cent NLP powder, 1 to 1.75 per cent mixture of Garlic + Ginger and 1 to 3 g $kg^{-1}$ feed NLP respectively to poultry diet did not influence significantly the feed consumption in birds. These observations are contradictory to present results where there was significant decrease in feed intake of birds due to provision of sole NLP, Ginger and their combinations as herbal growth promoters in the diets. However, it is pointed out that, the Giriraja birds consumed approximately less feed by (62 %) in 7th week as compared to expected BIS standard for 7th week recommended for broiler production. It is pointed out that Giriraja bird are dual purpose and one cannot expect the application of BIS standard. Hence one can expect an optimum growth performance on the consumption of feed noticed in treatment groups, though it was lower than that of the group without supplementation of any growth promoters.

At the end of starter phase (3rd week) total feed intake of Giriraja birds in $T_1$ (630.90) and $T_9$ (600.50) were significantly higher and lower, respectively over $T_2$ to $T_8$ groups. The cumulative feed intake of birds between $T_3$, $T_4$, $T_5$ $T_6$, $T_7$ and $T_8$ differ non-significantly. More or less same trend was maintained at finisher age of 7th week, where the average total feed intake was 2809.93, 2733.11, 2735.42, 2678.97, 2690.94, 2698.87, 2659.41, 2677.95 and 2594.26 $bird^{-1}$ in $T_1$, $T_2$, $T_3$, $T_4$, $T_5$, $T_6$, $T_7$, $T_8$ and $T_9$ groups, respectively. Significantly highest and lowest total feed intake was recorded in $T_1$ (control) and 1per cent NLP + 1.5 GP ($T_9$) groups, respectively. The birds from treatment groups consumed significantly more quantity of total feed by 5.44, 3.72 and 3.22 per cent under sole NLP ($T_2$ and $T_3$) sole GP ($T_4$ and $T_5$) and their mixture ($T_7$ and $T_8$) than that of ($T_9$) group, respectively. Thus one has to assess the lower cumulative consumption of feed on incorporation of herbal growth promotion in diet in reference to their impact on growth rate in birds in relation to economic viability.

## CONCLUSION

It was concluded that, saving on feed requirement of birds by 32 per cent during rearing from day old to 7th week of age in spite of lower feed consumption more live body weight by 54 per cent at 7th week of rearing due to more body weight gain by 52 per cent.This clearly indicates that, the combination group i.e. 1 per cent NLP + 1.5 per cent GP powder inclusion level in the diet of Giriraja poultry birds was better suited in respect of feed intake and growth.

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