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Molecular Characterization and Identification of *Phytophthora* Isolates from Different Citrus Orchards of Vidarbha Regions

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ABSTRACT

Phytophthora infections causing foot rot, root rot, dieback and gummosis in citrus are common in the Vidarbha region of Maharashtra. Seven *Phytophthora* isolates were obtained from leaves of symptomatic plants collected from seven locations of Vidarbha region using leaf bait method and specific media of CMA-PARPH. Out of four medium along with PARPH i.e. CMA-PARPH, OMA-PARPH, V8 agar juice -PARPH and PDA-PARPH, the growth of *phytophthora* was better on CMA-PARPH as recorded on 7th day of inoculation. The isolates of *Phytophthora* were confirmed morphologically and at molecular level. It was found that *P. nicotianae* was prominently present followed by *P. palmivora* in Vidarbha region of Maharashtra. A PCR based system with ITS region primers was used to characterize *Phytophthora isolates.* Five combinations of seven ITS primers viz. ITS4-ITS6, ITS1-ITS4, ITS1-ITS2, ITS4-ITS5 and ITS1-ITS6 were tried. The combination ITS4-ITS6 amplified the amplicon of size ~900bp in all isolates. ITS1-ITS4 showed ~800 bp amplicon in all seven isolates in different species of *phytophthora.* Approximately 300bp amplicon was observed when all the seven isolates were screened using ITS primer pair ITS1-ITS2. ITS4-ITS5 showed the amplicon of size ~850bp in all seven isolates whereas no amplification was observed in all the seven isolates when screened using ITS primer pair ITS1-ITS6. No amplification was observed in negative control. These primer pairs were used for the discrimination assay of *Phytophthora* which prominently found in citrus orchards.

Phytophthora spp. are the most destructive plant pathogens known to have a wide host range and severely affect citrus orchards and nurseries throughout the world (Erwin and Ribeiro, 1996 and Das *et al*., 2013). *Phytophthora* spp. are mainly responsible for wide destruction, causing varied symptoms *viz.* damping off, seedling rot, collar rot, fruit and root rot, leaf fall and fruit drop. More than 20 per cent seedling mortality has been reported in Central India due to *Phytophthora* spp. (Naqvi, 2000). Fungi of the genus *phytophthora*, a causal agent of gummosis are worldwide known as primary parasites of fine roots. *Phytophthora* root rot and gummosis are the most important soil borne diseases of Nagpur mandarin causing mortality, slow decline and yield loss of mature trees (Graham and Menge, 1999). *Citrus* spp. are prone to attack by more than 150 pathogens and disorders caused by fungal, viral and few bacterial pathogens right from nursery level to bearing stage resulting in severe losses. All citrus orchards in central India and other citrus cultivation belts of India are infected by *Phytophthora* disease. (Gade and Koche, 2012).

Phytophthora spp. cause the most serious and economically important soil borne diseases of citrus crop. Tree and crop production losses occurs due to damping-off of seedling in the seedbed, root rot and crown root in nurseries, foot rot and fibrous root and brown rot of fruits in groves. *Phytophthora* spp. also causes the decay of fibrous roots, especially on susceptible rootstocks in nurseries. In bearing groves, fibrous root rot damage cause decline and yield losses. The most important species include *Phytophthora parasitica, P. nicotianae, P. citrophthora* and *P. palmivora* reported to cause citrus disease in Maharashtra.

In India, every year huge losses to citrus production occur due to damage caused by biotic and abiotic factors among which most damaging one are Gummosis that causes serious losses in production and lowers the productivity. So, there is need to develop a diagnostic method to prevent the outbreak of disease.

Species identification is based primarily on the shape of the sporangia and the morphological features of the sexual structures. Other criteria widely used to distinguish species are growth temperature, growth rate, morphological (growth) characteristics in culture, and mating behavior (Bonants *et al.*, 2000). Due to rapid development of analytical techniques, new methods based

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on DNA amplification are often brought into practice, for example PCR, which is a relatively quick, cheap and easy method. These techniques are characterized by a simple procedure and do not require previous knowledge about the DNA sequences to be amplified or a high quality or quantity of DNA. In this study PCR using various combinations of ITS primers was used to characterize Phytopthora spp.

MATERAIL AND METHODS

In the present study, the leaf samples from citrus plants showing characteristic symptoms of *Phytophthora* were collected in order to isolate *phytophthora* sspecies. The *phytophthora* showing gummosis, root rot, barks cracking etc. are common symptoms that were observed from all locations of Vidarbha region.

Source of pathogen- Seven *Phytophthora* isolates were isolated and purified from leaf samples collected from symptomatic plants by leaf bait method and soil suspension method (Das *et al.*, 2013) from different locations of Vidarbha region which involved Main Garden Citrus Nursery, Akola, AICRP on Tropical Fruits, Dr. PDKV, Akola, Regional Research Station on Tropical Fruits Katol, Chargaon, Tiwasa Ghat, Shendurjana Ghat and Achalpur. The samples were placed in plastic bags to maintain soil moisture, transported to laboratory (Timmer *et al*., 1988).

The inoculated plates were incubated at 28^{0}C for 2-3 days and number of colonies of *Phytophthora* were counted. Soil in the second core was flooded with water, baited with pieces of citrus leaves, and placed in the incubator for 48 hr (Grimm and Alexander, 1973). The leaves were transferred to Petri dishes and examined for the presence of papillate sporangia. Subculture of *Phytophthora* from infected leaf pieces was easily identified by submerging infected leaf pieces in PARPH-CMA medium and transferring hyphal tips as they grew in the medium. Cultures were purified using hyphal tip method and maintained on selective medium and CMA at room temperature by adopting subsequent subculturing at regular intervals. The isolated *phytophthora* isolates were confirmed on the basis of morphological characters, sporangia, sporangiospores and swelling of the vegetative mycelium and seven days old mycelial growth was taken for DNA isolation and for further study.

DNA Extraction:- DNA was isolated from pure culture using standard protocol with some modifications (Sambrook, 1989) whereas DNA from soil sample was extracted using DNA Extraction Kit (Genetix Biotech Make). DNA was quantified after RNase treatment on Nanophotometer (Eppendorf Make).

Polymerase Chain Reaction (PCR):- Polymerase Chain Reaction (PCR) amplification of the ITS region of the template DNA was performed using primers ITS1 to ITS7 in various combinations as described by Cooke et al., 2000. PCR was conducted in 20µl reaction volume using 0.2ml PCR tubes. Each reaction mixture contained: dNTPs (10mM), $MgCl_2$ (25mM), forward primer (10pmol/µl), reverse primer (10pmol/µl), 10X PCR buffer, *Taq* DNA polymerase (1U) and 1µl template DNA. Different PCR conditions were used for different primer sets. Amplification was carried out using mastercycler PCR machine (Applied Biosystem Make). The PCR profiling for each primer pair was optimized. Initial denaturation for all the primer pair was 94^{0}C for 3-5 min, then denaturation was carried out at 94^{0}C for 30 sec- 1min. Annealing temperature for primer pair ITS4-ITS5 and ITS4-ITS6 was 50^{0}C, for ITS1-ITS2 and ITS1-ITS6 was standardized at 54^{0}C whereas for ITS1-ITS4 annealed at 55^{0}C. PCR was done for 35 cycles at given temperature for 30 sec. The extension of annealed product was carried out at 72^{0}C for 30 sec and for 5-10 min respectively. The amplified DNA (PCR products) was electrophoresed on 1% agarose gel stained with ethidium bromide. The gel was observed under a Gel Doc system (Biovis, Mumbai).

RESULTS AND DISCUSSION

Isolation, Purification and Morphological Characterization of the isolates

The leaf samples were collected from plants showing characteristics symptoms of *phytophthora* from various region of Vidarbha. The common symptoms shown by phytophthora are dieback, gummosis, root rot, bark cracking, damping off (except Akola region), brown rot of fruits, reduction in fruit size, etc. from all locations of Vidharbha region. The expression of symptoms depends on the epidemiology of disease. There is variation in environmental parameters as well as availability of resources e.g. temperature, irrigation facilities, fungicidal use etc. An infected seedling rapidly shows drying symptoms, when moisture is abundant and temperature is favorable for fungal growth. Favorable conditions of optimum temperature (25-27^{0}C) and long periods of wetting (18 plus hours) continue, disease spreads to fruit throughout the canopy.

Isolation of *phytophthora* was carried out from the leaves collected from symptomatic plants of all the seven locations of Vidarbha region for which baiting method was used (Das et al., 2016). Isolation of pure culture from infected plant parts or soil sample the brown edged leaf disc was done by baiting method and transferred to different media viz. corn meal agar, oat meal agar, V8 agar juice and potato dextrose agar in combination with PARPH. The growth of *phytophthora* was better on CMA-PARPH as recorded on 7th day of inoculation results obtainedare shown in fig 1.

The purified isolates were subjected to morphological test using inverted and compound microscope and confirmed the basic morphology of *phytophthora*. The sporangial morphology was also examined for shape, presence or absence of papilla and sporangiophore branching. The characteristics features of *phytophthora* reported viz. papillate sporangia, ovide sporangia and non septed hypha growth were recorded in the isolates under study (Fig 2). All the seven isolates showed characteristic morphological features similar to that of *P. nicotianae* and found relevant as shown in fig 3. Morphological confirmation of *Phytophthora* from pure culture was done against the morphogenic descriptions given by Bush *et al.*, 2006.

It revealed from morphological observations that *P. nicotianae* is present in all the samples collected from seven locations whereas *P. palmivora* from main citrus nursery, Dr. PDKV, Akola and Achalpur only. Other species of *Phytophthora* were not reported in the present study because no morphological similarity seen related to other strains of *Phytophthora. P. nicotianae* isolates produced spheroid sporangium that were noncaduceus and papillate, whereas *P. palmivora* isolates produces sympodial sporangiophores that were caduceus and with short pedicel.

Validation of ITS marker on the *phytophthora* isolated from different location

The validation using molecular marker detection technology are more convenient, effective and specific assays have opened the door to greater use of these test for detecting plant pathogen. PCR, RT-PCR, Real time PCR, Nested PCR, Nucleic acid hybridization, microarray, southern blotting and many more molecular techniques are having importance in disease diagnosis of *phytophthora*. Molecular characterization of plant pathogenic fungi is accomplished by PCR amplification of ITS region. Internal transcribed spacer (ITS) refers to the spacer DNA situated between the small-subunit ribosomal RNA (rRNA) and large-subunit rRNA genes in the chromosome or the corresponding transcribed region in the polycistronic rRNA precursor transcript. Sequence comparison of the ITS region is widely used in taxonomy and molecular phylogeny as it is routinely amplified due to its small size associated to the availability of highly conserved flanking sequences; it is easy to detect even from small quantities of DNA due to the high copy number of the rRNA clusters; it undergoes rapid concerted evolution via unequal crossing-over and gene conversion.

PCR was carried out using ITS primer combinations ITS4-ITS6, ITS1-ITS2, ITS1-ITS4, ITS4-ITS5 and ITS1-ITS6. These five combinations of ITS primers were used to amplify DNA isolated from pure culture of *phytophthora* from seven locations. The combination ITS4-ITS6 amplified the amplicon of size ~900 bp in all isolates (Fig 4a). ITS1-ITS4 showed ~800 bp amplicon in all the seven isolates (fig 4b) in different species of *phytophthora*. Approximately 300 bp amplicon was observed when all the seven isolates were screened using ITS primer pair ITS1-ITS2 (fig 4c). ITS4-ITS5 showed the amplicon of size ~850 bp in all seven isolates as shown in (Fig 4d) however no amplification was observed when the isolates screened using ITS primer pair ITS1-ITS6. No amplification was observed in negative control. Similar results were recorded by many scientists.

Discrimination assay for identification of *Phytophthora*

Phytophthora is a pseudofungus and having convergent evolution so not evolved as fungi group. The wall composition of *phytophthora* is made up of cellulose as like eukaryotic species and all fungi group are having cell wall composition of chitin. Because of this the management practices followed which are chitin based are not effective on *Phytophthora*, so there is need of different management practices. At field level it is difficult to discriminate infection of *Phytophthora* in infected zone of citrus orchard. The variation in amplicon size found after PCR lead to differentiation of the species from one another. The primer pairs showing unique band in all the isolates can be used for detection of *Phytophthora*.

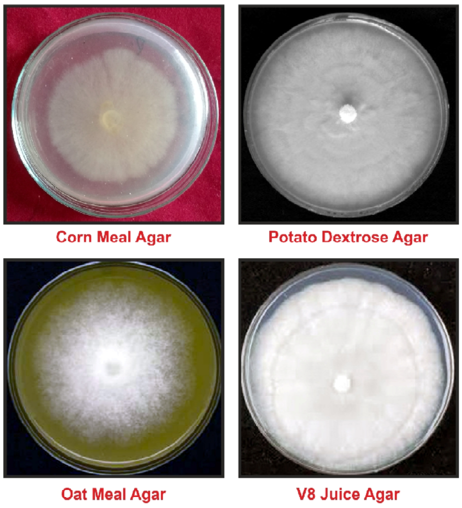
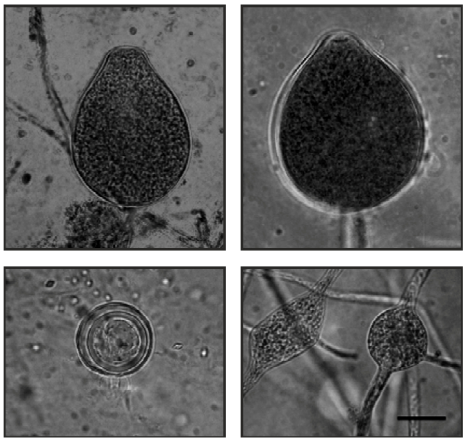


Fig. 1 : Pure growth of *Phytophthora* on CMA-PARPH



(Source : Safaiefarahani *et al.*, 2013)

Fig. 2 : Morphological variations in *P.* mycelia growth

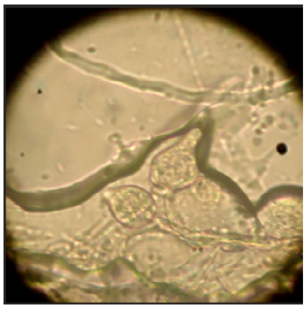
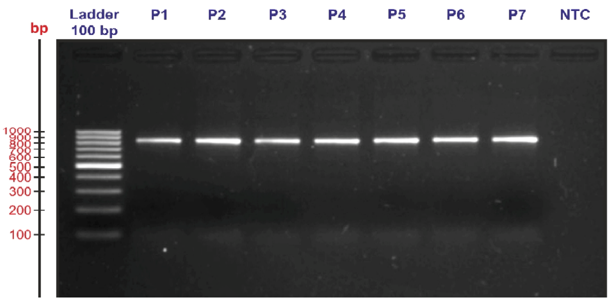
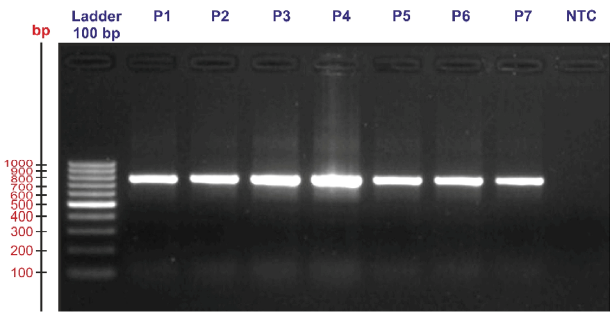


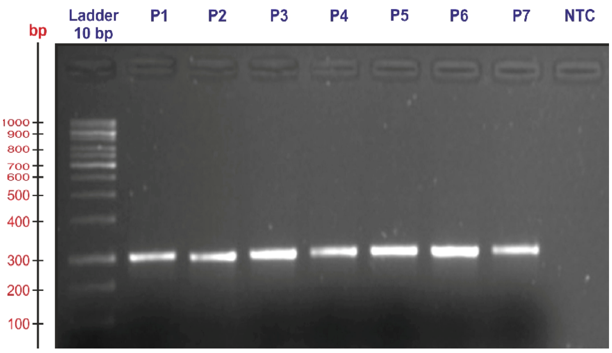
Fig. 3 : Morphology of *Phytopthora* isolates



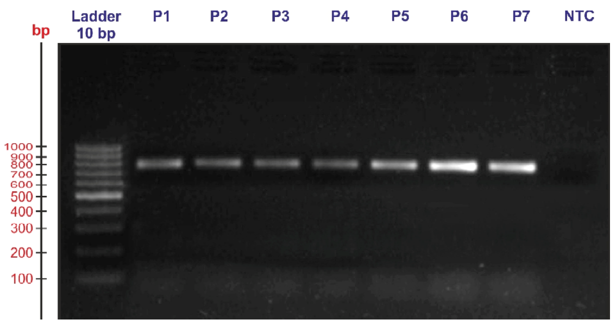
4a- Primer pair ITS4-ITS6



4b- Primer pair ITS1-ITS4



4c- Primer pair ITS1-ITS2



4d- Primer pair ITS4-ITS5

Fig. 4 : Amplification obtained using various ITS Primer pairs

Coding of Phytopthora isolates

Code No	Location of Collection	Code No	Location of Collection
P1	Main Garden Citrus Nursery, Akola	P2	AICRP on tropical Fruits, Dr. PDKV, Akola
P3	Regional Research Station on Tropical Fruits, Katol	P4	Tiwasa Ghat
P5	Akot	P6	Shendurjana Ghat
P7	Achalpur	NTC	No template Control

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AKH-09-5: A Promising American Cotton Genotype for Sustained Productivity under Rainfed Cultivation in Maharashtra

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ABSTRACT

Cotton is important fibre crop of India which plays a vital role in Indian economy. The main reasons for low productivity of cotton in Maharashtra is its cultivation under rainfed condition. Intermilitant dry spells and cession of mansoon in middle of September results in low productivity. There is a need to develop high yielding variety which can withstand biotic and abiotic stresses. The newly developed American cotton variety AKH-09-05 is high yielding with good fibre qualities and tolerant to major sucking pests and disease. It was recorded consistantly good performance for seed cotton yield over the checks in University, State and AICRP trials and hence may becomes goal option for rainfed cotton growing area of Maharashtra.

Cotton (*Gossypium hirsutum* L.) is an important fibre crop and plays a vital role as a cash crop in commerce of many countries such as India, USA, China, Pakistan, Uzbekistan, Australia and Africa. In India cotton is being grown on area of 105 lakh hectare with production of 351 lakh bales and productivity of 568 kg ha^{-1}. In Maharashtra, it is cultivated on 38 lakh hectare with production of 88.5 lakh bales and productivity 396 kg ha^{-1} lint (Anonymous, 2018). The main reason for low productivity of cotton in Maharashtra is its cultivation under mostly rainfed condition and growing cotton on medium and shallow soils. Intermittent dry spells during June to August followed by cessation of monsoon activity in middle of September results in low productivity. There is a need to have high yielding genotypes which can withstand biotic and abiotic stresses. Development of new genotype with higher yield with good fibre quality are the primary objectives of cotton breeding programmes. At Cotton Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola the work on genetic enhancement on American cotton is being carried out since last five decades resulting in the release of several high yielding cotton varieties i.e. DHY-286 a late maturing variety (200-210 days), AKH-081 an early maturing variety (150 days), PKV Rajat (170 days), AKH-8828 (170 days) and AKH-9916 (170-180 days) medium duration varieties. However, the medium duration varieties are susceptible to sucking pests except DHY-286 and AKH-9916. The AKH-09-5, American cotton new genotype is high yielding with good fibre qualities and tolerant to sucking pests and diseases.

MATERIAL AND METHODS

Concentrated efforts are continued to have a high yielding variety with desirable fibre properties. In this context, crosses were made between high yielding line AKH-9913 and AKH-8801, line with good fibre qualities

Table 1: Summary performance of AKH-09-5 in station trial

Trial / Year	*Location*	*Seed Cotton Yield (kg/ha)*			*CD at 5 %*	*CV %*
		AKH-09-5	*PKV Rajat (Ch)*	*AKH-8828 (Ch)*		
2011-12	Akola	1340	977	1060	274.67	12.22
Increase over (%)			**37.2**	**26.4**		
			Lint Yield (kg/ha)			
		496	369	437	108.02	12.62
Increase over (%)			**34.4**	**13.5**		

1,4,5,6,8,9,10 Assistant Professor, 2, 7 Professor and 3. Juni9or Research Assistant, Cotton Research Unit, Dr. PDKV,Akola

Table 2: Summary performance of AKH-09-5 for seed cotton yield in multi location trials conducted in Vidarbha region

Trial / Year	Location	Seed Cotton Yield (kg ha^{-1})			
		AKH-09-5	PKV Rajat (Ch)	AKH-8828 (Ch)	AKH-9916(Ch)
2012-13	6	1226	987	902	916
2013-14	5	1046	849	772	1055
2015-16	6	1246	987	917	875
2016-17	6	1640	1107	1321	1173
Overall Mean	**23**	**1300**	**989**	**987**	**1003**
Increase over (%)		**31.5**	**31.7**	**29.7**	

Table 3: Summary performance of AKH-09-5 for Lint yield in multi location varietal trials of Vidarbha region

Trial / Year	Location	Lint Yield (kg ha^{-1})			
		AKH-09-5	PKV Rajat (Ch)	AKH-8828 (Ch)	AKH-9916(Ch)
2012-13	6	401	334	337	356
2013-14	3	416	354	332	463
2015-16	5	491	446	415	386
2016-17	4	629	405	456	465
Overall Mean	**18**	**479**	**384**	**384**	**406**
Increase over (%)			**24.7**	**24.7**	**17.9**

Table 4: Summary performance of AKH-09-5 for seed cotton yield (kg ha^{-1}) in SMVT trials of Maharashtra

Trial / Year	Loc.	Seed	Cotton Yield (kg ha^{-1})				
		AKH-09-5	PKV Rajat (Ch)	AKH-8828 (Ch)	NH-615 (Ch)	NH-545 (Ch)	Phule 688 (Ch)
2012-13	9	1328	957	868	1062		973
2013-14	11	1236	928	900	1075		1039
2014-15	9	1102	927	766	862	906	804
2015-16	11	990	827	818	719	780	902
2016-17	10	1190	1027	991	1116	1139	1030
General Mean (50)	**1165**	**931**	**872**	**964**	**937**	**956**	
Increase over (%)		**25.2**	**33.9**	**20.8**	**16.3**	**21.8**	

followed by selections for symmetrical good plant type with fibre qualities and tolerance for various diseases and pests. Desirable resistant /tolerant plants were selected in F_2 generation and plant to row selections were made in F_3 to F_6 generations. Uniform promising lines were evaluated for yield potential and finally a most promising one was evaluated in Station trial, Regional Multi location Trials, State Multi location Trials and AICRP Cotton trials during 2011-12 to 2016-17.

RESULTS AND DISCUSSION

Yield performance

The proposed variety AKH-09-5 was compared with PKV Rajat and AKH-8828 in Station Trial during 2011-12. It has recorded high productivity under rainfed condition and showed 37.2 and 26.4 per cent higher seed cotton yield over the checks PKV Rajat and AKH-8828 (Table 1).

Table 5: Summary performance of AKH-09-5 for lint yield (kg ha^{-1}) in SMVT trials of Maharashtra

Trial / Year	Location	Lint Yield (kg ha^{-1})					
		AKH-09-5	PKV Rajat (Ch)	AKH-8828 (Ch)	NH-615 (Ch)	NH-545 (Ch)	Phule 688 (Ch)
2012-13	7	483	391	329	392		341
2013-14	5	420	317	290	315		348
2014-15	4	423	341	359	337	409	328
2015-16	7	442	393	398	347	384	414
2016-17	4	437	392	408	406	382	365
General Mean (27)	**445**	**371**	**356**	**360**	**390**	**363**	
Increase over (%)		**20.0**	**24.5**	**23.7**	**11.7**	**22.6**	

Table 6: Performance of AKH-09-5 for seed cotton yield and lint yield in AICCIP trials

Trial / Year	Location	Seed Cotton Yield (kg ha^{-1})		Lint Yield (kg/ha)	
		AKH-09-5	NH-615 (ZC)	AKH-09-5	NH-615(ZC)
Nt. Br. 02 (b)	Banswara	2196	2024	621	637
2015-16	Bharuch	2262	1958	723	674
	Indore	744	683	246	273
	Akola	1404	1298	518	450
	Nanded	1074	918	362	334
	CICR Ngp.	1627	569	515	201
	Mean (6)	**1551**	**1242**	**498**	**428**
Increase over (%)		**24.9**		**16.2**	
Pro. Br. 03(b)	Akola	1684	1464	549	549
2016-17 (CZ)	Nanded	613	734	268	268
	Bharuch	3116	2068	701	701
	Banswara	1989	2227	762	762
	Mean (4)	**1851**	**1623**	**570**	**570**
Increase over (%)		**14.0**		**10.0**	
General Mean (10)	**1671**	**1394**		**485**	
Increase over (%)		**19.8**		**13.3**	

Similarly, the genotype AKH-09-5 was evaluated in Regional Multi location Trials (MLT) in comparison with PKV Rajat, AKH-8828 and AKH-9916 during 2012-13 to 2016-17. On the basis of average of 23 MLTs, it has recorded 31.5, 31.7 and 29.7 per cent higher seed cotton yield over the checks PKV Rajat, AKH-8828 and AKH-9916, respectively (Table 2). It has recorded 24.7 per cent each higher lint yield over PKV Rajat and AKH-8828 (Table 3). Bhatade and Ansingkar (2003) reported on an average 22.5 and 19.3 per cent increased seed cotton yield and lint yield of NH-545 over the check NH-452 in Regional Multi location Trials.

During the period of 2012-13 to 2016-17 the proposed genotype AKH-09-5 was also evaluated in State Multi Location Trials (SMVT) conducted in three different regions of Maharashtra viz., Vidarbha, Marathwada and Western Maharashtra utilizing five checks. In SMVT trials, the genotype AKH-09-5 exhibited higher seed cotton yield (50 trials) to the extent of 25.2 per cent over PKV Rajat, 33.9 per cent over AKH-8828, 20.8 per cent over NH-615,

Table 7: Performance of AKH-09-5 for fibre quality parameters in regional and state multi location trials

Year	Trial	AKH-09-5	PKV Rajat (Ch)	AKH-8828 (Ch)	AKH-9916 (Ch)	NH-615 (Ch)	NH-545 (Ch)	Phule 688 (Ch)
Upper half mean length (mm)								
2015-16	PDKV Br.04 b	29.3	27.5	28.3	25.5			
2015-16	SMVT Hir	29.4	24.5	26.7		28.6	25.4	26.1
2016-17	PDKV Br.04 b	29.9	26.8	26.3	27.1			
2016-17	SMVT Hir	30.9	26.3	27.5		30.1	27	27
General Mean (4)		**29.9**	**26.3**	**27.2**	**26.3**	**29.4**	**26.2**	**26.6**
Micronaire value (ug/inch)								
2015-16	PDKV Br.04 b	3.6	4.4	3.9	3.7			
2015-16	SMVT Hir	4.1	4.8	3.4		3.5	4.2	3.8
2016-17	PDKV Br.04 b	4.1	4.9	4.7	4.7			
2016-17	SMVT Hir	3.8	4.6	4.4		3.8	4.6	4.2
General Mean (4)		**3.9**	**4.7**	**4.1**	**4.2**	**3.7**	**4.4**	**4**
Bundle strength (g/tex)								
2015-16	PDKV Br.04 b	30.7	26.9	27.9	27.9			
2015-16	SMVT Hir	27.9	24.6	25.6		27.2	26.5	28.9
2016-17	PDKV Br.04 b	29.9	26.8	26.3	27.1			
2016-17	SMVT Hir	27.5	28	28.1		26.5	28.6	29.9
General Mean (4)		**29**	**26.6**	**27**	**27.5**	**26.9**	**27.6**	**29.4**
Uniformity index								
2015-16	PDKV Br.04 b	82	81	82	80			
2015-16	SMVT Hir	82	79	81		82	80	80
2016-17	PDKV Br.04 b	84	81	80	81			
2016-17	SMVT Hir	83	80	82		83	81	81
General Mean (4)		**83**	**80**	**81**	**81**	**83**	**81**	**81**
Fibre elongation								
2015-16	PDKV Br.04 b	5.9	5.5	5.7	5.6			
2015-16	SMVT Hir	5.5	5.6	5.4		5.5	5.8	5.9
2016-17	PDKV Br.04 b	5.5	5.7	5.8	6.3			
2016-17	SMVT Hir	5.8	5.8	5.8		5.5	5.8	5.9
General Mean (4)		**5.7**	**5.7**	**5.7**	**6**	**5.5**	**5.8**	**5.9**

16.3 per cent over NH-545 and 21.8 per cent over Phule 688, respectively (Table 4). The genotype AKH-09-5 has recorded 20, 24.5, 23.7, 11.7 and 22.6 per cent higher lint yield over the checks PKV Rajat, AKH-8828, NH-615, Nh-545 and Phule 688, respectively (Table 5).

As regards the performance of proposed genotype AKH-09-5 in All India Coordinated Research Project on Cotton trials (AICRP), it was evaluated in central zone during 2015-16 and 2016-17(Table 6). Based on average of 10 trials, it has recorded19.8 and 13.3 per cent increased seed cotton yield and lint yield over the zonal check NH-615, there by indicating its wider adaptability and stability for seed cotton yield. Meshram et. al. (2003) reported 18.52 per cent increased seed cotton yield of PKV Hy-4 in AICRP cotton trials conducted over the years.

The fibre quality of AKH-09-5 was evaluated in different trials and presented in Table 7 and 9. The results indicated that it has good fibre qualities, superior for Upper Half Mean Length, Fibre Strength, Micronaire value and Uniformity Index over the check varieties.

Table 8: Performance of AKH-09-5 for fibre qualities in AICCIP Trials

Trial/Year	Location	Upper half mean length (UHML)		Micronaire value (ug inch^{-1})		Bundle strength (g tex^{-1})	
		AKH-09-5	NH-615(ZC)	AKH-09-5	NH-615(ZC)	AKH-09-5	NH-615(ZC)
Nt. Br. 02 (b)	Banswara	30.9	27.2	4.2	3.5	25.0	26.8
2015-16	Bharuch	29.9	29.4	4.8	4.3	25.5	25.6
	Indore	27.5	28.4	2.6	3.2	22.6	27.5
	Akola	29.3	30.1	4.3	4.1	27.8	27.7
	Nanded	27.4	26.6	4.1	3.3	25.5	28.1
	CICR Ngp.	27.9	27.4	4.1	3.7	26.5	27.6
	Mean (6)	**28.8**	**28.2**	**4.0**	**3.7**	**25.5**	**27.2**
Pro Br. 03 (b)	Akola	29.6	29.7	4	3.6	30.4	29.5
	Bharuch	30.3	29.7	4.6	4.5	32.1	31.7
	Banswara	30.3	29.6	4.2	4.3	23.7	25.5
	Mean (3)	**30.1**	**29.7**	**4.3**	**4.1**	**28.7**	**28.9**
General Mean (9)	**29.2**	**28.7**	**4.1**	**3.8**	**26.6**	**27.8**	

Reaction to pest and diseases:

As regards the field reaction to the pest and diseases (Table 9 and 10), the genotype AKH-09-5 found tolerant to jassids, *Myrothecium* leaf spot, grey mildew and Bacterial Leaf Blight disease.

Table 9: Reaction of AKH-09-5 to Sucking pests and Boll worm complex in AICCIP trial (Pro Br. 03 2016-17)

Insect Pests	AKH-09-5		DCH-32 (SC)		DHY-286 (RC)	
Jassids	**Grade**	**Count**	**Grade**	**Count**	**Grade**	**Count**
Akola	I	3.70 (1.92)	I	6.00 (2.43)	I	3.00 (1.68)
Nanded	III	8.10 (2.93)	III	8.6 (3.01)	II	11.75 (3.49)
Bharuch	1.2 (MR)	4.0 (2.12)	4 (HS)	22.40 (4.78)	1.1 (MR)	3.60 (2.02)
Banswara	II	9.33 (3.05)	IV	13.67 (3.70)	I	4.33 (2.08)
White flies/3 leaves						
Akola		9.80 (3.09)		3.80 (1.91)		13.70 (3.68)
Nanded		10.90(3.37)		13.30 (3.69)		11.20 (3.41)
Bharuch		20.90 (4.57)		9.60 (3.17)		35.40 (5.98)
Banswara		15 (3.86)		18.67 (4.32)		6.0 (2.44)
Av. loculi damage at harvest						
Akola		9.54 (17.96)		2.09 (8.20)		13.55 (21.53)
Nanded		6.30 (14.51)		8.20 (16.63)		8.70 (17.15)
Bharuch		10.86(19.20)		23.29 (28.79)		17.06 (24.33)
Banswara		N.A.		N.A.		N.A.

Table 10: Reaction of AKH-09-5 to various diseases in AICCIP screening trial during 2016-17(Pro. Br. 03)

Diesease	Locations	AKH-09-5	LRA-5166
Bacterial Leaf Blight (Grade)	Akola	1 (R)	3 (MS)
	Nanded	II(MR)	III (MS)
	Bharuch	1(R)	2 (MR)
	Banswara	N.A.	N.A.
Myrothecium Leaf spot (Grade)	Akola	1 (R)	1 (R)
	Nanded	II (MR)	III (MS)
	Bharuch	N.A.	N.A.
	Banswara	N.A.	N.A.
Grey mildew (Grade)	Akola	1(R)	1(R)
	Nanded	0 (DF)	I (R)
	Bharuch	N.A.	N.A.
	Banswara	N.A.	N.A.

Conclusion:

The medium duration variety AKH-09-5 is high yielding, a stable genotype, tolerant to jassids, *Myrothecium* leaf spot, grey mildew and Bacterial Leaf Blight diseases. In addition it has superior fibre qualities and farmers may get higher net economic return and hence, will be proposed for release in Maharashtra state for rainfed cultivation.

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Effect of Split Application of Nutrients Through Fertigation on Growth, Yield and System Productivity in Cotton-Onion Crop Sequence

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ABSTRACT

A field experiment was conducted during the year 2011-12, 2012-2013 and 2013-14 at Department of Agronomy, Dr.PanjabraoDeshmukhKrishiVidyapeeth, Akola to study the effect of split application of N and K fertilizers on growth, yield attributes of cotton and onion, system productivity and to economize the fertilizer requirement for cotton-onion sequence under fertigation. The experiment was laid out in randomized block design with four replications and five treatments imposed for both cotton and onion crop having four different levels of drip fertigation in five splits at 50 per cent, 75 per cent, 100 per cent and 125 per cent of recommended dose of N and K given through fertigation and P as basal compared with 100 per cent soil application of fertilizers. The experimental site was established with inline drip irrigation system (16 mm) lateral laid out at 120 cm with 60 cm dripper spacing.

Experimental results revealed that, in cotton all the growth parameters viz. plant height, dry matter accumulation per plant, sympodial branches and yield attributes viz. bolls picked and seed cotton yield per plant were substantially enhanced by drip fertigation level at 125 per cent recommended dose of N and K than lower fertigation levels (50, 75 and 100 per cent) and over conventional soil application with 100 per cent RDNK Kg ha^{-1}. As a consequence of better growth and yield attributes, drip fertigation at 125 per cent RDNK ha^{-1} had recorded higher seed cotton yield of 3680 Kg ha^{-1} , 3326 Kg ha^{-1} and 3184 Kg ha^{-1} during 2011-12 , 2012-13 and 2013-14 respectively. Application of 125 per cent recommended dose of N and K through fertigation significantly increased all the growth attributes and yield attributing components of onion viz. Bulb polar diameter, equatorial diameter and weight of fresh bulb which was found comparable with 100 per cent level of N and K through fertigation. Drip fertigation at 125 per cent recommended dose of N and K applied through fertigation recorded significantly higher onion bulb yield of 36.03 t ha^{-1}, 37.78 t ha^{-1} and 36.33 t ha^{-1} during 2011-12 ,2012-13 and 2013-14 respectively. Drip fertigation at 75 per cent recommended dose of N and K ha^{-1} did not differ significantly in relation to growth, yield and uptake of nutrients compared to 100 per cent RDNK ha^{-1} applied through soil by conventional method indicating 25 per cent fertilizer saving through fertigation in individual crop of cotton and onion. The NPK uptake was favourably increased with higher level of fertigation compared with lower levels and soil application method; however, nutrient use efficiency (NUE) showed a declining trend with increasing level of N and K fertilizer by drip fertigation irrespective of different doses. Drip fertigation was found better in increasing NUE compared to conventional soil application of fertilizers in both cotton and onion crops. Split application of N and K through fertigation at 125 per cent recommended dose ha^{-1} significantly improved the cotton equivalent yield ,GMR, NMR and economic efficiency of the cotton-onion sequence under fertigation, whereas, B:C ratio of the system was maximum at 100 per cent fertigation of RDNK $ha^{-1.}$ It could be concluded that application of 100 per cent recommended dose of N and K in five splits found to be best for maximizing the yield and beneficial in increasing the system productivity and economic returns of cotton-onion sequence.

Cotton and Onion are the most important commercial crops grown in irrigated area of India and these crops are grown under diverse agro-climatic conditions. Improper irrigation and nutrient management are the main reason of low productivity of both these crops.As a commercial crop, cotton (*GossypiumhirsutumL.*) is the

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most important fibre crop of India and it is grown in about 9.59 million hectares under diverse agroclimatic conditions as a white gold and king of fibre and also aptly called as "white gold".Bt cotton hybrids now constitute more than 90 per cent of the cotton area sown in the country.Maharashtra is the leading state in respect of area (41.46 lakh hectare) under cotton cultivation, which shares 35.21 per cent of total cotton growing area of the country (117.73 lakh hectare) but ranks third in production and 10^{th} in productivity (303 kg ha^{-1}). (Cotton Advisory Board Report,2013).Bt cotton being highly exhaustive crop with regard to plant nutrients, fairly large quantities of nutrients are required (SatyanarayanaRao and Setty, 2002). Among the many strategies to improve the cotton productivity, split application of fertilizers especially nitrogen and potassium has proven more productive and profitable (Mahmood-ul-Hasan*et al*., 2003).

Similar to cotton, onion is also the major cash crop giving high return within short period. It is the only crop which will fit after cotton under high input management like drip irrigation and fertigation. India is the second largest producer of onion in the world, though; India significantly lags behind in the per hectare productivity of the onion. Drip fertigation provides an efficient method of fertilizer delivery and the availability of soil moisture and nutrients at root zone of the crops which influences the uptake of nutrients, growth and yield of the crop. Among the various factors responsible for high crop yield, the use of appropriate quantity of fertilizer at proper time plays a vital role in enhancing the productivity of onion. Onion requires higher level of N, P and K fertilizer for maximum yields than most other vegetable crops. The shallow roots and dense population of onion make them responsive to fertilizers. Application of fertilizers at appropriate stages of crop growth ensures a regular flow of both water and nutrients resulting in increased growth rates and higher yields.

Increasing demand for irrigation water coupled with depleting ground water sources calls for efficient use of water. Therefore, there is need for efficient irrigation methods to both these crops. The present scenario of flood irrigation should give away to controlled irrigation, such as drip irrigation which offers enormous for economy of irrigation water and fertilizer chemicals. In conventional method, there is a heavy loss of nutrients due to leaching, denitrification, evaporation and fixation in the soil. Drip irrigation and fertigation are technologies which improve both water and fertilizer use efficiency to a great extent. Fertigation gives flexibility of fertilizer application, which enables the specific nutritional requirement of the crop to be met at different stages of its growth. Split application of fertilizers ensures required nutrients in right time and in right quantity for getting higher yield with minimum loss of nutrients. Nitrogen and potassium fertilizers are water soluble and play a major role in the growth and development of both these crops.Drip irrigation and fertigation are technologies which improve both water and fertilizer use efficiency to a great extent. In general, injection of fertilizers into irrigation water gives a better crop response than either band or broadcasting. Fertigation gives flexibility of fertilizer application, which enables the specific nutritional requirement of the crop to be met at different stages of its growth. Split application of fertilizers ensures required nutrients in right time and in right quantity for getting higher yield with minimum loss of nutrients.

Traditionally onion is taken as a second crop after kharif crops like Pearl Millet and Groundnut. Most of the farmers are taking wheat crop after harvesting of early duration Bt Cotton or any early duration hybrid cotton. But when the cotton crop is taken under fertigation in kharif season, it is the alternative to the farmer to grow the second crop of onion under the same set of drip irrigation system to make the sequence cropping more profitable as both the crop are cash crop and the system will be more profitable when the resources like fertilizers and water will be utilised more efficiently under precision agriculture. The inclusion of vegetable crop like onion in a sequence after kharif crop like cotton will be more remunerative. In view of the above, it was felt appropriate to study the effect of split application of nutrients on growth,yield and system productivity in cotton-onion crop sequence..

MATERIAL AND METHODS

A field experiment was conducted during the year 2011-12, 2012-2013 and 2013-14 at Department of Agronomy, Dr.PanjabraoDeshmukhKrishiVidyapeeth, Akola to study the effect of split application of N and K fertilizers on growth, yield attributes,quality, nutrient uptake, system productivity and to economize the fertilizer requirement in Bt cotton-onion crop sequence under fertigation. The experiment was laid out in randomized block design with four replications and five treatments imposed having four different levels of drip fertigation in five splits at 50 per cent, 75 per cent, 100 per cent and 125 per cent of recommended dose of N and K given through fertigation and P as basal compared with 100 per cent soil application of fertilizers for cotton and onion.

The soil of experimental plot was clayey in texture, low in organic carbon, slightly alkaline in reaction, low in available nitrogen and phosphorus and fairly high in available potassium. The soil had 32.96 per cent moisture at field capacity and 16.40 per cent at permanent wilting point with a bulk density of 1.21 g cc^{-1}.Cropping history of the experimental plot was almost practically uniform before conducting the experiment. The experimental site was established with inline drip irrigation system (16 mm) with emitters of 4 lph capacity lateral laid out at 120 cm with 60 cm dripper spacing. The average emission uniformity of drip irrigation system was estimated as 91 per cent for all the treatments.The recommended dose of fertilizers (N&K) was applied as per the treatments through fertigation tank of 90 lit. capacity.Phosphorus (50 $Kgha^{-1}$) was applied as basal and N and K as urea and murate of potash respectively through drip irrigation in five splits as per the treatments and growth stages of cotton(10 % at basal, 20 % at 20 DAS, 25% at 40 DAS, 25% at 60 DAS and 20 % at 80 DAS.) and onion (10 % at 10 DAT, 20 % at 20 DAT, 25% at 40 DAT, 25% at 60 DAT and 20 % at 80 DAT).In conventional soil application method, half nitrogen and full dose of P and K were applied as basal at sowing and remaining half dose of N was top dressed at 30 DAS and 60 DAS in cotton. However in onion half of the nitrogen and full dose of phosphorus and potash were applied as basal application at the time of sowing in the conventional methods. Remaining half dose of nitrogen was top-dressed at 30 and 60 days after transplanting as per the treatments. Irrigation water was applied through drip irrigation on alternate day at the rate of 100 per cent crop evapotranspiration level to both the crop. The Bt cotton variety ACH-155 and Agri Found Light Red variety of onion was used for experimentation. The recommended dose of fertilizers for cotton and onion was 100:50:50 NPK Kg ha^{-1} and 100:50:80 NPK Kg ha^{-1} respectively. The Onion crop was raised under drip fertigation on raised bed. Immediately after sowing, irrigation was given uptosoaking of entire bed and subsequent irrigations were scheduled once in two days. The total quantity of water applied (including effective rainfall) to cotton was 469.22 mm, 622.3 mm and 652.8 mm , and for onion it was 564.90 mm,479.19 mm and 523.55 mm during the year 2011-12,2012-13 and 2013-14 respectively.

RESULTS AND DISCUSSION

The results of the present study as well as relevant discussion have been summarized under following heads:

Growth and yield attributes of cotton

Pooled mean of threeyears (Table 1) revealed that concomitant increase in all the growth attributes were noticed with each increasing level of drip fertigation of recommended dose of N and K from 50 to 125 per cent. In cotton, among the drip fertigation levels drip fertigation at 125 per cent recommended dose of N and K (P as basal) significantly improved the plant height, dry matter accumulation per plant and sympodial branches at harvest. Drip fertigation of N and K fertilizers with higher levels of 125 per cent RDNK ha^{-1} registered their superiority in enhancing all the growth attributes over lower fertigation levels (50, 75 and 100 per cent) and over conventional method of soil application with 100 per cent recommended dose of NPK Kg ha^{-1}.However the plant height at 100 per cent N and K through soil application (T_1) was found comparable with 75 per cent drip fertigation. The plants were taller when the fertilizers were applied through drip fertigation in split doses as compared to soil application of fertilizers. Higher frequency of irrigation and increased availability of soil moisture under drip irrigation coupled with fertigation might have led to effective absorption and utilization of nutrients and better proliferation of roots resulting in better canopy growth. The favourable increase in growth attributes in terms of plant height and dry matter accumulation due to drip fertigation was reported by Bhalerao*et al*.(2011) , and Ayyadurai*et al*. (2014). The limited root zone and the reduced amount of mineralization in the restricted wetting zone might be the probable reason for the reduced nutrient availability and reduction in growth of cotton under drip irrigation combined with soil application of fertilizers. Increased growth parameters with 125 per cent recommended N and K ha^{-1} might be due to presence of favourable microclimate to the plants and application of sufficient nutrients in readily available form would have accelerated the proliferation of growth regulators such as auxin (IAA) and cytokinin which in turn stimulated the action of cell elongation and cell division and resulted in increased growth of cotton. Similar findings were reported by Kavitha*et al*.(2007) in tomato and Anitta (2010) in maize. Fertilizer application through irrigation water takes the nutrients in dissolved state throughout the root zone. The dissolved nutrients have the distribution along the wetting soil volume. This might have resulted in more uptake of nutrients and growth resulting in higher dry matter production.Veeraputhiran (2000), Sathyaprakash (2007), Bhalerao*et al*.(2011) reported higher dry matter accumulation when fertilizers were applied through fertigation in splits. Nalayani*et al.* (2012), Gokila (2012) and Ayyadurai*et al.* (2014) also reported that split application of N and K in more split enhanced the dry matter production.

Higher number of sympodia per plant in fertigation of N and K splits might be due to higher uptake of nutrients and further vegetative growth of the cotton plant. Veeraputhiran (2000),Sathyaprakash (2007), Bhalerao*et al*.(2011), and Gokila (2012) have reported the beneficial effect of higher level of N and K fertigation on sympodial branches in cotton which indicated that Bt cotton required more nutrients for enhancing the yield attributes (Sankarnarayanan*et al*.,2004).

As indicated in Table1 ,the yield attributing characters like number of bolls picked per plant and seed cotton yield per plant influenced significantly due to split application of recommended dose of nitrogen and potassium ha^{-1} through fertigation and higher level of RDNK ha^{-1} through fertigation at 125 per cent recommended dose of N and K favourably increased these yield attributes than other lower level of fertigation and soil application method of applying fertilizers.However,75 per cent fertigation and 100 per cent soil application of recommended N and K ha^{-1} were equally effective in enhancing number of picked bolls per plant and seed cotton yield per plant. Average boll weight was found at par among the treatments during the course of investigation. Lower values of all the yield attributing characters were observed at lower levels of 50 per cent fertigation.The substantial increase in number of picked bolls per plant and seed cotton weight per plant due to higher levels of fertigation than lower level and conventional method was associated with the improvement in various growth attributes viz. plant height, number of sympodial branches and dry matter accumulation per plant and its subsequent translocation to sink. The cumulative effect of these finally improved the number of picked bolls per plant and seed cotton yield per plant, because the ability of cotton crop to produce and support more number of bolls depends on dry matter accumulation and its translocation to sink. The increase in more number of bolls per plant under higher level of fertigation might be due to enhanced availability and uptake of nutrients to enhance photosynthesis, expansion of leaves and translocation of nutrients to reproductive parts as compared to lower rate of N and K given through fertigation and over conventional soil application of fertilizers. Similar advantage of higher level of fertigation of nutrients in improving the number of picked bolls per plant and weight of seed cotton per plant were reported earlier Bhattoo*et al*.(2008), Sahadeva Reddy and Aruna (2010) Bhalerao*et al.*(2011) and Gokila (2012).

Seed cotton yield

Drip fertigation levels had marked and favourable influence on growth and yield parameters viz. plant height, number of sympodial branches $plant^{-1}$, dry matter production, number of picked bolls per plant and seed cotton yield per plant of cotton during three years of study. These favourable influences on these parameters were reflected on seed cotton yield due to various treatments.(Table2).

The perceptible effect of higher levels of fertigation at 125 per cent RDNK ha^{-1} in promoting the growth and yield parameters of the crop had definite say on the final seed cotton yield. The seed cotton yield linearly increased with increasing levels of fertilizers applied through fertigation. Drip fertigation at 125 per cent RDNK ha^{-1} had recorded higher seed cotton yield of 3680 Kg ha^{-1}, 3326 Kg $ha^{-1,}$3184 Kg ha^{-} during 2011-12, 2012-13 and 2013-14 respectively and3397 Kg ha^{-1} in pooled mean which was followed by 100 per cent drip fertigation of RDNK ha^{-1} with seed cotton yield of 3362 Kg ha^{-1}, 3030 Kg $ha^{-1,}$2907 Kg $ha^{-1}$and 3099 Kg ha^{-1}respectively. Drip fertigation at higher level of 125 per cent fertigation recorded an increased yield of 24.85 per cent over conventional soil application in pooled yield of three years.Increased nutrient availability and absorption by the crop at the optimum moisture supply coupled with frequent and higher nutrient supply by fertigation and consequent better formation and translocation of assimilates from source to sink might have increased seed cotton yield under fertigation. Fertilizer application of 100 per cent N and K through drip increased yield significantly over 100 per cent NPK through soil indicating benefit of drip for better utilization of applied nutrients. The results are in conformity with the findings of Hadole*et al*.(2012) and Nalayani*et al*.(2012).

Drip fertigation at 75 per cent RDNK ha^{-1} recorded comparable yield with 100 per cent recommended dose of fertilizers applied through soil by conventional method during the study and indicating 25 per cent fertilizer saving through fertigation when compared to conventional soil application of fertilizers. The saving of fertilizers might be due to reduction in losses of nutrients through volatilization and leaching and better movement of nutrients under drip fertigation as against soil application of fertilizers as reported by Yende*et al*.(2003) and Pawar*et al*.(2013). The seed cotton yield under drip irrigation with soil application of recommended dose of N and K was significantly lower and inferior over higher-level of drip fertigation. Soil application of fertilizers under drip irrigation might have restricted the mineralization of nutrients and enhanced the losses due to volatilization and this might be the probable reason for the lower yield under drip irrigation with soil application of nutrients. Nalayani*et al*. (2012),Singh *et al*.(2012) and Ayyadurai*et al*.(2014) also reported that drip fertigation had greater advantages and increased seed cotton yield as compared to broadcast application of fertilizer nutrients.

Nutrients uptake and nutrients use efficiency

As indicated in Table 2,it was observed that, different fertigation levels and soil application method showed significant influence on nutrients (N,P and K) uptake by plant. The nutrient uptake was favourably increased with higher level of fertigation compared with lower levels and soil application method. Higher uptake of N, P and K were observed at 125 per cent levels of N and K fertigation. Progressive increase in applied level of N and K correspondingly increased the nutrient uptake and lower uptake was noticed at lower level of fertigation (50 per cent) However, drip fertigation at 75 per cent RDNK ha^{-1} and soil application method (T_1) were comparable in respect of N,P and K uptake. The higher available soil moisture provided due to continuous water supply at alternate days under drip irrigation led to higher availability of nutrients in the soil and thereby increased the nutrient uptake under drip fertigation levels in splits was the result of increased biomass production due to continuous availability of water and nutrients to the crop.

An application of N given through fertigation not only stimulated vegetative growth and foraging capacity of roots, but also encouraged the absorption and translocation of more nutrients under higher drip fertigation levels. Due to improved growth characters, the plants tend to take more nutrients from the soil since it was available nearer to root zone at required level. Reducing the fertilizer dose resulted in reduced availability of nutrients which might be the reason for lower uptake of nutrients by crop at lower doses of fertilizers as indicated in the present study.In conventional method of soil application of fertilizers, application of large quantity of fertilizers as a single dose resulted in higher volatilization losses of nutrients and resulted lower the availability of nutrients during later growth stages of crop. This might be the reason for lower uptake of nutrients by crop, when fertilizers are applied by conventional method .Further application of nutrients in more number of splits through drip irrigation resulted in minimum or no wastage of nutrients either through deep percolation or volatilization ultimately led to higher uptake of all the nutrients as reported by Raskar (2004).Higher nutrient uptake with higher level of fertigation over soil application was also

Table1: Growth, yield attributes and seed cottonyield as influenced by different fertigation treatments (Pooled mean of three years)

Treatments	Plant Height (cm)	Sympodial branches plant^{-1}	DMW Plant^{-1} 120 DAS (g)	No. of picked bolls plant^{-1}	verage e boll weight (g)	Seed cotton yield plant^{-1} (g)	Seed cotton yield (kg ha^{-1}) 2011-12	2011-12	2011-12	2011-12
T_1: DI +100% RDNK soil application	129.33	24.80	374.61	36.86	4.76	173.90	2740	2519	2399	2553
T_2: DF+ 50% RDNK	123.05	22.38	344.05	31.94	4.65	151.91	2350	2212	2076	2213
T_3: DF+ 75 % RDNK	131.35	25.26	382.25	38.96	4.77	181.30	2894	2620	2516	2677
T_4: DF+ 100 % RDNK	135.85	27.50	392.05	44.75	4.79	210.69	3362	3030	2907	3099
T_5: DF+ 125 % RDNK	142.45	30.28	417.11	49.08	4.82	232.25	3680	3326	3184	3397
S. E. (m) ±	1.94	0.79	7.62	1.26	0.06	6.13	102	95	87	89
C. D. at 5%	5.93	2.44	22.48	3.74	NS	18.68	315	294	269	274
CV%	8.91	9.07	10.42	7.79	4.50	9.56	11.26	8.96	9.56	8.39

reported by Veeraputhiran*et al*.(2005), Bhalerao*et al*.(2011), and Ayyadurai*et al*.(2014).The similar trend was observed in respect of total uptake as observed in case of individual nutrient uptake.

Fertilizer use efficiency (FUE) showed a declining trend with increasing level of N and K application by drip fertigation(Table 2). Drip fertigation with 50 per cent RDNK ha^{-1} has recorded a higher NUE of 20.8 kg seed cotton kg^{-1} nutrient applied as against 12.7 kg seed cotton kg^{-1} nutrient applied at 125 per cent RDNK fertigation. In spite of higher nutrient uptake at higher fertigation doses, 125 per cent RDNK fertigation has resulted in lower NUE. The conventional method of soil application of fertilizers at 100 per cent RDNK ha-1 (T_1) has resulted lower NUE of 12.0 than all the fertigation treatments which clearly indicates the superiority of drip fertigation over conventional soil application of N and K fertilizers. The nutrient use efficiency was considerably increased in drip fertigation compared to soil application of N and K fertilizers. This could be attributed to regular application of N and K (as high as five splits in drip fertigation) combined with irrigation water in the active root zone of the crop and their interaction in even N distribution in the soil with minimum leaching of nutrients away from the root zone. This results are in accordance with the findings of Gokila (2012) and Pawar*et al*.(2013).

Growth and yield attributes of onion

The growth and yield attributes of onion viz. plant height,dry matter accumulation,weight of fresh bulb, bulb dry weight, bulb polar diameter, equatorial diameter, were found higher at 125 per cent RDNK ha^{-1} which was found comparable with 100 per cent level of N and K fertigation as indicated in Table 3. Drip fertigation at 75 per cent of RDNK and 100 per cent soil application treatments were comparable for all the characters. Concomitant increase in all the growth attributes were noticed with each increasing level of drip fertigation of recommended dose of N and K from 50 to 125 per cent. Maximum growth and yield attributes with higher level of fertigation might be due to frequent application of fertilizers at convenient interval during the crop growth period which increased the available nutrient status in the root zone thus increased the uptake and growth.

Effect on onion bulb yield

A perusal of the data presented in Table 2 on onion bulb yield (t ha^{-1}) as influenced by different treatments indicated that different drip fertigation levels and soil application of fertilizers had a marked and significant influence on onion bulb yield. Drip fertigation at 125 per cent recommended dose of N and K applied through fertigation recorded significantly higher pooled onion bulb yield of 36.79 t ha^{-1} which was followed by 100 per cent fertigation of RDNK ha^{-1}(36.53 t ha^{-1}). Fertigation at 75 per cent N and K ha^{-1} recorded higher, but comparable yield with 100 per cent RDNK ha^{-1} applied through soil indicating 25 per cent fertilizer saving compared to conventional soil application method of applying fertilizers as earlier reported by Savita *et al* .The higher level of fertigation (125 per cent) registered 21.99 per cent increase

Table 2: Nutrients uptake and nutrients use efficiency as influenced by different fertigation treatments in cotton (Pooled of three years)

Treatments	Nutrient uptake (Kg ha^{-1})	Nutrient use efficiency(kg kg^{-1})		
		N	P	K
T_1: DI +100% RDNK soil application	91.23	26.54	68.15	12.0
T_2: DF+ 50% RDNK	79.47	22.45	56.99	20.8
T_3: DF+ 75 % RDNK	95.20	28.05	70.76	16.8
T_4: DF+ 100 % RDNK	108.42	31.10	79.52	14.5
T_5: DF+ 125 % RDNK	124.63	34.63	92.47	12.7
S. E. (m) ±	3.22	0.92	2.35	—
C. D. at 5%	9.93	2.83	7.24	—
CV%	8.32	7.19	9.64	—

Table 3: Growth, yield attributing characters and yield of Onion at harvest as influenced by different treatments (Pooled of three years)

Treatments	Plant Height(cm)	Dry matter (g)Plant^{-1}	Weight of fresh bulb at harvest(g)	Bulb polar diameter (mm)	Bulb Equatorial diameter (mm)	Onion Bulb Yield(t ha^{-1})			
						2011-12	2011-12	2011-12	Pooled
T_1: DI +100% RDNK soil application	66.95	21.01	115.75	52.84	59.35	28.15	29.56	28.34	28.68
T_2: DF+ 50% RDNK	60.68	18.38	104.39	46.45	54.03	25.03	26.16	24.91	25.37
T_3: DF+ 75 % RDNK	71.30	22.68	120.00	55.95	61.95	31.00	32.53	30.95	31.49
T_4: DF+ 100 % RDNK	77.08	26.12	131.20	63.08	66.51	35.83	37.57	36.21	36.53
T_5: DF+ 125 % RDNK	78.45	26.97	133.21	63.78	67.26	36.03	37.78	36.33	36.79
S. E. (m) ±	1.86	0.82	3.61	1.78	1.45	1.00	1.08	1.03	0.98
C. D. at 5%	5.73	2.45	11.11	5.49	4.45	3.07	3.33	3.16	3.00

Table 4: Nutrients uptake and nutrient use efficiency as influenced by different fertigation treatments in onion (Pooled of three years)

Treatments	Nutrient uptake(Kg ha^{-1})			Nutrient use efficiency (kg kg^{-1})
	N	P	K	
T_1: DI +100% RDNK soil application	121.33	48.70	137.02	101.2
T_2: DF+ 50% RDNK	108.24	41.92	115.69	177.9
T_3: DF+ 75 % RDNK	133.67	54.36	146.14	147.4
T_4: DF+ 100 % RDNK	156.00	62.60	175.50	129.3
T_5: DF+ 125 % RDNK	166.22	65.71	184.42	103.8
S. E. (m) ±	5.06	1.97	5.15	—
C. D. at 5%	15.60	6.07	15.88	—

in onion bulb yield over soil application of fertilizers showing the superiority of fertigation over conventional soil application of fertilizers.

Nutrients uptake and nutrients use efficiency in onion

As indicated in Table 4, the increasing trend of nutrient uptake was observed as the fertigation levels increased from 50 per cent to 125 per cent level. It is revealed that with increasing level of fertigation, uptake of N,P and K was also increased.125 percent and 100 per cent fertigation showed higher uptake than other level of fertigation. Similarly, higher nutrient use efficiency was recorded in the treatments where fertilizers are applied through fertigation in splits as compared to soil application of fertilizers. The present study indicates that the fertigation methods irrespective of different doses was found better in increasing the NUE when compared to conventional soil application of fertilizers as lowest values of 101.2 Kg kg^{-1} was registered under soil application of fertilizers. The NUE was considerably increased in drip fertigation compared to soil application of N and K fertilizers which might be due to split application of N and K to the active root zone of the crop with minimum leaching losses of nutrients away from the root zone.

System Productivity (Cotton Equivalent Yield tha^{-1}), system economics (GMR,NMR, B: C ratio and Economic efficiency)

The pooled data presented in Table 5 revealed that cotton equivalent yield of cropping system was significantly influenced with the application of 125 per cent recommended dose of N and K applied through drip fertigation(p as basal) in five splits (12.57 t ha^{-1}),however it was comparable to application of 100 per cent RDNK ha^{-1} fertigation(12.23 t ha^{-1}) during the period of experimentation. The fertigation with 75 per cent RDNK ha^{-1} was found comparable (10.55 t ha^{-1}) with 100 per cent soil application of fertilizers (9.72 t ha^{-1}) in respect of cotton equivalent yield indicating 25 per cent saving of fertilizers in fertigation compared to soil application method. The promising results in respect of cotton equivalent yield were also reported by Narayana *et al*. (2008) when different vegetable crops were grown after Bt cotton crop. Nalayini*et al*.(2012) also obtained the similar results when different field crops and vegetables were grown followed by Bt cotton.

It was noticed that (Table 5) fertigation at 125 per cent recommended dose of N and K registered the maximum GMR(₹ 508054 ha^{-1}) and NMR(378497 ha^{-1}) when pooled over three years being comparable with values of 100 per cent fertigation. The higher level of 125 per cent fertigation of RDNK ha^{-1} registered 29.32 per cent increase in NMR than 100 per cent soil application of N and K through conventional method. The data presented in Table 6 indicated that split application of N and K fertilizers also improved the economic efficiency (net returns per day) of the system and higher economic efficiency (system profitability per day) was noticed with higher level of 125 per cent RDNK ha^{-1} followed by 100 per cent fertigation of RDNK ha-1.The B: C ratio of the system(pooled mean) was maximum at 100 per cent

Table 5: Cotton Equivalent Yield (t ha^{-1}), GMR (ha^{-1}) and NMR (ha^{-1}) of Cotton-Onion sequence as influenced by different fertigation treatments

Treatment	Cotton equivalent yield (t ha^{-1})				System GMR (Rs. ha^{-1})				System NMR (Rs. ha^{-1})			
	2011-12	**2012-13**	**2013-14**	**Pooled**	**2011**	**2012**	**2013**	**Pooled**	**2011-12**	**2012-13**	**2013-14**	**Pooled**
T_1: DI +100% RDNK soil application	9.78	9.91	9.48	9.72	395477	400516	383269	393087	270137	274552	257784	267491
T_2: DF+ 50% RDNK	8.61	8.75	8.30	8.55	348310	353798	335543	345884	232539	237071	219359	229656
T_3: DF+ 75 % RDNK	10.64	10.75	10.25	10.55	430380	434300	414103	426261	309564	313076	293294	305311
T_4: DF+ 100 % RDNK	12.32	12.42	11.96	12.23	497804	501605	482745	494051	373752	377227	358925	369968
T_5: DF+ 125 % RDNK	12.69	12.77	12.27	12.57	512880	515858	495423	508054	383196	386082	366214	378497
S. E. (m) ±	0.36	0.37	0.34	0.35	10801	10822	9996	9170	10801	10822	9996	9170
C. D. at 5%	1.11	1.14	1.05	1.09	33276	33341	30796	28252	33276	33341	30796	28252

Table 6: Benefit Cost ratio and Economic Efficiency (Rs day^{-1} ha^{-1}) of Cotton-Onionsequence as influenced by different fertigation treatments

Treatment	B:C Ratio				Economic Efficiency(Rs day^{-1} ha^{-1})			
	2011-12	2012-13	2013-14	Pooled	2011	2012	2013	Pooled
T_1: DI +100% RDNK soil application	3.16	3.18	3.05	3.13	740	752	706	733
T_2: DF+ 50% RDNK	3.01	3.03	2.89	2.98	637	650	601	629
T_3: DF+ 75 % RDNK	3.56	3.58	3.43	3.52	848	858	804	836
T_4: DF+ 100 % RDNK	4.01	4.03	3.89	3.97	1024	1033	983	1014
T_5: DF+ 125 % RDNK	3.95	3.97	3.83	3.92	1050	1058	1003	1037
S. E. (m) ±	–	–	–	–	–	–	–	–
C. D. at 5%	–	–	–	–	–	–	–	–

fertigation of RDNK ha-1 with values of 3.97 . These higher values of B:C ratio in these treatments might be due to yield advantage in 100 per cent treatment than other treatments and due to less rate of increase in yield from 100 to 125 per cent dose of N and K fertigation and also due to higher cost of cultivation in 125 per cent fertigation treatment as more fertilizers were added in these treatment.

CONCLUSION

Tt is concluded that,in Cotton-Onion crop sequence for increasing system productivity, economic returns and nutrient use efficiency, it is recommended to apply 100 per cent N and K in five splits through drip and P as basal through soil application.

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Diversification in Cotton + Soybean (4:10) – Rabi Strip Intercropping System under Mechanization in Rainfed Condition of Vidarbha Region of Maharashtra

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ABSTRACT

An experiment was conducted during 2013-14 to 2016-17 at All India Coordinator Research Project for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.). Treatments consist of seven cropping patterns and two nutrients management levels tested in split plot design with three replications. On the basis of pooled analysis, the results revealed that, among the various treatments combination Cotton + soybean (4:10)- safflower and an application of 100% RDF (through inorganic fertilizer) recorded significantly higher cotton equivalent yield (2103 and 1824 kg ha^{-1}), net monetary returns (Rs. 45850 and 33394 ha^{-1}), B:C ratio (2.01 and 1.75), RWUE (2.91 and 2.52 kg $ha^{-1}mm^{-1}$), sustainable value and yield index (0.94 & 0.81 and 0.85 & 0.61), crop productivity and system productivity (8.25 & 7.43 and 5.76 & 5.00 kg ha^{-1} day^{-1}) and (179.80 & 136.28 and 125.62 &91.46 Rs ha^{-1} day^{-1}) than the rest of the treatment combinations. Chemical properties of the soil were found non-significant. However, integrated nutrient management and chemical nutrient management were found to be non-significant in respect of organic carbon content of soil and available nitrogen i.e.4.89 & 4.85 g kg ha^{-1} and 192.95 & 194.90 kg ha^{-1}, respectively.

In most multiple cropping systems developed by small holders, productivity in terms of harvestable products per unit area is higher than under sole cropping with the same level of management. Yield advantages can range from 20 to 60% and achieve due to reduction of pest incidence and more efficient use of nutrients, water and solar radiation. Enhanced yields in diversified cropping systems may result from a variety of mechanisms such as more efficient use of resources like (light, water, nutrients) or reduced pest damage. Intercropping, which breaks down the monoculture structure, can provide pest control benefits, weed control advantages, reduced wind erosion, and improved water infiltration.

Indian agriculture is now facing second generation problems like rising or lowering of water table, nutrient imbalance, soil degradation, salinity, resurgence of pest and diseases, environmental pollution and decline in farm profit. Crop diversification shows lot of promise in alleviating these problems through fulfilling the basic needs and regulating farm income, withstanding weather aberrations, controlling price fluctuation, ensuring balanced food supply, conserving natural resources, reducing the chemical fertilizer and pesticide loads, environmental safety and creating employment opportunity and to maintain soil health.

Crop diversification through intercropping has been shown to improve crop productivity and profitability, conservation of resources and provide a kind of biological insurance against risks and aberrant rainfall behaviour in rainfed condition (Dutta and Bandyopadhyay, 2006). Strip cropping is a form of intercropping comprises growing of soil conservation and soil depleting crops in alternate strips. Besides increasing overall productivity and income, intercropping of legumes with cereals/ millets/oilseeds/ pulses helps in improving physical properties of soil and building up of soil fertility.

It also acts as a powerful tool in minimization of risk in farming. These considerations make a strong case for farm/crop diversification in India. Crop diversification in India is generally viewed as a shift from traditionally grown; less remunerative crops to more remunerative crops. Market infrastructure development and certain other price related supports also induced to crop shift. Higher profitability and the resilience/stability in production also induced crop diversification. Crop diversification and large

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number of crops are practiced in rainfed areas also reduced the risk factor of crop failures due to drought.

Thus, the present investigation was undertaken to "Diversification in cotton+ soybean (4:10)-rabi strip intercropping system under mechanization in rainfed condition with the objectives of to intensify and diversify the system to meet out domestic needs of small and marginal farmers with find out the most suitable *rabi* crop for cotton-soybean based sequence cropping and to evaluate the economics of different cropping system.

MATERIAL AND MEHTHODS

The field study was carried out during the *kharif* season of 2013-14 to 2016-17 at All India Coordinator Research Project for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) on a clayey soil with FC 34.2 (%), PWP 14.2 (%), BD 1.36 (Mg M^{-3}) and depth of soil was 132 cm. Soil was medium in available nitrogen (182 kg ha^{-1}) and phosphorus (19.8 kg ha^{-1}) and high in available potassium (341.6 kg ha^{-1}) with pH 7.8, EC 0.2 dsm^{-1} and organic carbon of soil 4.7g kg^{-1}. Experiment consists of seven cropping pattern treatments in main plot C_1- Sole cotton, C_2-Sole soybean-chickpea, C_3- Sole soybean-linseed, C_4-Sole soybean - safflower, C_5- Cotton + soybean (4:10)-chickpea, C_6-Cotton + soybean (4:10)-linseed and C_7-Cotton + soybean (4:10)-safflower and with two nutrients management treatments *i.e.* F_1- 100 % RDF and F_2 - 50 % N +100 % P and K applied through inorganic fertilizer + 50 % N through gliricidia leaves lopping after one month after sowing.

After the harvest of soybean crop, land was prepared with the help of tractor drawn rotavator and in *rabi* season crops are sown with tractor drawn seed drill. An application of 100 per cent RDF applied to the treatment of sole cotton/soybean/chickpea/linseed/safflower and 55 per cent RDF (on area basis) applied to the treatment of cotton + soybean (4:10)-chickpea /linseed/safflower crops. In *kharif* season, 45:55:30 kg ha^{-1} NPK was applied to the treatment of cotton + soybean (4:10) row proportions in rabi season 55 % RDF was applied to the sequence crop of chickpea, linseed and safflower crops respectively. Total rainfall received during the experimentation period was 860.7, 518.7 and 724.1 in 45, 26 and 43 rainy days in the years 2013-14, 2015-16 and 2016-17 respectively.

RESULTS AND DISCUSSION

i. Yield

On the basis of three years data, results showed that, seed cotton yield, seed yield of soybean, chickpea, linseed and safflower was recorded higher in sole cropping system than yield obtained in the treatment of cotton + soybean (4:10) row proportion (*i.e.* 1550, 1825, 668,119 and 1078 kg ha^{-1}, respectively (Tables 1, 2 and 3).

An application of 100% RDF recorded higher seed cotton and soybean yield (1129 and 1479 kg ha^{-1}). The results showed that yield of soybean, chickpea, linseed and safflower were more or less equal in seed as well as in fodder yield. Reduction in yield of cotton / soybean/chickpea/linseed/safflower crops in treatment of cotton + soybean (4:10) row proportion can be attributed to the less number of plants per unit area. Similar, trend of results also recorded in the stalk yield of cotton and straw yield of soybean and also in straw yield of *rabi* crops.

ii. Cotton equivalent yield:

Pooled results showed that, the treatments of cotton + soybean (4:10) – safflower and sole soybean – safflower was being at par with each other and significantly superior than rest of treatments *i.e.* 2103 and 2041 kg ha^{-1} (Table 4). This might be due to favourable effect of soybean and succeeding *rabi* crops on cotton growth as there was no intercrop competition for growth due to the strip sowing. When cotton sown with soybean in *kharif* season and safflower in *rabi* season, this attributed to better productivity of cotton, soybean and safflower recorded the higher cotton equivalent yield due to the higher remunerative and better market prices. Increase productivity of cotton with additional yield of mixed crops of soybean and *rabi* crops specially the yield of safflower helped in increasing the cotton equivalent yield over treatments of sole cotton. These results are in conformity with the findings of Gill and Ahlawat, (2006) and Sankaranarayanan *et al.*, (2012). They reported that Maize + soybean - French bean cropping system gave higher equivalent yield compared to other cropping systems.

On the basis of pooled, results showed that an application of 100% RDF recorded significantly higher

Table.1. Seed cotton yield and cotton stalk yield as influenced by treatments of cropping pattern and nutrient management

Treatments	Seed Cotton Yield (kg ha^{-1})				Cotton Stalk Yield(kg ha^{-1})			
	2013-14	2015-16	2016-17	Mean	2013-14	2015-16	2016-17	Mean
A. Main Plot (Cropping Pattern)								
C_1 - Sole cotton	1489	1331	1832	1550	3115	2076	2418	2536
C_2 - Sole soybean -Chickpea	-	-	-	-	-	-	-	-
C_3 - Sole soybean -Linseed	-	-	-	-	-	-	-	-
C_4 - Sole soybean - Safflower	-	-	-	-	-	-	-	-
C_5 - Cotton + soybean (4:10)-Chickpea	957	804	960	907	2061	1254	1267	1527
C_6 - Cotton + soybean(4:10)-Linseed	954	800	951	902	1958	1249	1255	1487
C_7 - Cotton + soybean(4:10)-Safflower	958	806	971	911	2008	1257	1281	1515
B. Sub Plot -Nutrient Management								
F_1 - 100 % RDF	1176	992	1220	1129	2485	1547	1703	1881
F_2 - 50 % N +100 % P and K applied through inorganic fertilizer + 50 % N through *Gliricidia*	1003	879	1137	1006	2086	1371	1729	1632

Table.2. Soybean seed yield and soybean straw yield as influenced by treatments of cropping pattern and nutrient management

Treatments	Soybean Seed Yield (kg ha^{-1})				Soybean Straw Yield(kg ha^{-1})			
	2013-14	2015-16	2016-17	Mean	2013-14	2015-16	2016-17	Mean
A. Main Plot (Cropping Pattern)								
C_1 - Sole cotton	-	-	-	-	-	-	-	-
C_2 - Sole soybean -Chickpea	2459	1075	1943	1825	1819	1311	2160	1763
C_3 - Sole soybean -Linseed	2459	1075	1943	1825	1819	1311	2160	1763
C_4 - Sole soybean - Safflower	2459	1075	1943	1825	1819	1311	2160	1763
C_5 - Cotton + soybean (4:10)-Chickpea	1484	613	1155	1084	1215	747	1284	1082
C_6 - Cotton + soybean(4:10)- Linseed	1509	616	1115	1080	1216	752	1240	1069
C_7 - Cotton + soybean(4:10)-Safflower	1500	619	1161	1093	1294	755	1291	1113
B. Sub Plot -Nutrient Management								
F^1 - 100 % RDF	2025	879	1532	1479	1559	1073	1703	1448
F_2 - 50 % N +100 % P and K applied through inorganic fertilizer + 50 % N through *Gliricidia*	1931	812	1554	1432	1491	990	1729	1403

Table.3 Chickpea, linseed and safflower seed and straw yield (Kg ha^{-1}) as influenced by the treatments of cropping pattern and nutrient management (2013-14 to 2016-17)

Treatments	2013-14	2015-16	2016-17	MeaN	2013-14	2015-16	2016-17	Mean
A. Cropping Pattern		**Chickpea Yield**				**Chickpea Straw Yield**		
C_2 - Sole soybean-chickpea	1023	1018	344	668	825	793	385	574
C_5 - Cotton +soybean (4:10)-Chickpea	563	540	201	412	485	669	224	372
B. Nutrient Management								
F_1 - 100 % RDF	815	722	284	539	682	600	318	465
F_2 - 50 % N +100 % P and K applied through inorganic fertilizer + 50 % N through *Gliricidia*	772	837	261	541	627	648	291	461
B. Cropping Pattern		**Linseed Yield**			**Linseed Straw Yield**			
C_3 - Sole soybean-Linseed	175	170	71	119	188	197	79	167
C_6 - Cotton +soybean (4:10)- Linseed	91	105	51	89	93	107	57	100
B. Nutrient Management								
F_1 - 100 % RDF	131	129	61	120	135	153	68	135
F_2 - 50 % N +100 % P and K applied through inorganic fertilizer + 50 % N through *Gliricidia*	134	146	61	118	146	150	68	132
C. Cropping Pattern		**Safflower Yield**			**Safflower Straw Yield**			
C_4 - Sole soybean- Safflower	1102	1117	965	1078	735	1101	815	968
C_7 - Cotton +soybean (4:10)- Safflower	662	625	514	605	455	608	648	600
B. Nutrient Management								
F_1 - 100 % RDF	907	913	788	840	617	824	824	796
F_2 - 50 % N +100 % P and K applied through inorganic fertilizer + 50 % N through *Gliricidia*	857	829	765	843	573	785	806	772

Table.4. Cotton equivalent yield as influenced by the treatments of cropping pattern and nutrient management

Treatments		Cotton Equivalent Yield (kg ha^{-1})			
		2013-14	2015-16	2016-17	Mean
A. Main Plot (Cropping Pattern)					
C_1 -	Sole cotton	1489	1331	1832	1550
C_2 -	Sole soybean -Chickpea	1989	1490	1552	1725
C_3 -	Sole soybean -Linseed	1601	1075	1359	1361
C_4 -	Sole soybean - Safflower	2223	1510	2032	2041
C_5 -	Cotton + soybean (4:10)-Chickpea	2231	1653	1880	1943
C_6 -	Cotton + soybean(4:10)-Linseed	1956	1410	1741	1708
C_7 -	Cotton + soybean(4:10)-Safflower	2252	1677	2192	2103
	S.Em.±	44.0	45.2	39.8	27.9
	C.D.at 5 %	135.6	139.9	122.8	86.2
B. Sub Plot -Nutrient Management					
F_1 -	100 % RDF	2027	1505	1821	1824
F_2 -	50 % N +100 % P and K applied through inorganic fertilizer + 50 % N through *Gliricidia*	1899	1394	1776	1728
	S.Em.±	22.6	27.3	31.1	17.0
	C.D. at 5 %	68.8	82.8	NS	52.4
C. Interaction effect					
	S.Em.±	60.0	72.3	82.1	45.1
	C.D.at 5 %	NS	NS	NS	NS

cotton equivalent yield 1824 kg ha^{-1} over 50% N through inorganic and 50% N through glyricidia loppings.

Interaction effect was found to be non–significant. This was due to inorganic fertilizer application to cotton and its residual effect on safflower. The yield increase was attributed to significant increase in plant height, sympodial branches plant $^{-1}$, bolls plant $^{-1}$ and yield boll $^{-1}$ with recommended dose of fertilizer. These results are in close agreement with the findings of Tomar *et al.*, (2000) and Gawai and Pawar (2005).

iii. Economics:

Pooled results showed that ,treatments of cotton + soybean (4:10)-safflower and sole soybean-safflower found at par with each other and recorded significantly higher gross monetary returns compared to the rest of the treatments *i.e.* Rs. 91147 and Rs.87887 ha^{-1}, respectively. However, in respect of net monetary returns, cotton + soybean (4:10)-safflower recorded significantly higher net monetary returns than rest of the treatments (Rs.45850 ha^{-1}).

In respect of nutrient management treatments, results showed that, 100% RDF recorded significantly higher gross monetary returns (Rs.79023 ha^{-1}), net monetary returns (Rs.33394 ha^{-1}) and B:C ratio (1.75) than 50% N +100% P and K applied through inorganic fertilizer + 50% N through g*liricidia.* This might be due to favourable effect of soybean and succeeding *rabi* crops on cotton growth as there was no intercrop competition for growth as well as soil moisture, nutrients and solar radiation due to the strip sowing. Due to more productivity and market rates of the mixed crops and low cost of cultivation also helped in increasing higher economics returns. Tanaka *et al.*, (2007) reported that, crop sequence has a significant effect on cropping system for net returns. A cropping systems approach may offer opportunities

Table.5. GMR, NMR and B:C ratio as influenced by the treatments of cropping pattern and nutrient management

Treatments	Gross Monetary Returns (kg ha^{-1})				Net Monetary Returns (kg ha^{-1})				B:C Ratio			
	2013-14	2015-16	2016-17	Pooled Mean	2013-14	2015-16	2016-17	Mean	2013-14	2015-16	2016-17	Pooled Mean
A. Main Plot (Cropping Pattern)												
C_1 - Sole cotton	81768	65155	79029	67515	55230	31561	37243	27919	3.08	1.96	1.90	1.71
C_2 - Sole soybean - Chickpea	105204	74057	67611	74500	61614	21265	10813	18351	2.41	1.41	1.19	1.33
C_3 - Sole soybean - Linseed	84620	53586	59198	58879	50461	5823	10721	10815	2.48	1.10	1.23	1.23
C_4 - Sole soybean - Safflower	116982	74928	87991	87887	76973	27987	38997	39308	2.93	1.56	1.80	1.81
C_5 - Cotton + soybean (4:10)- Chickpea	121100	81567	81774	84327	81267	37587	33864	37370	3.09	1.92	1.71	1.80
C_6 - Cotton + soybean(4:10)-Linseed	105360	69601	75447	74198	73524	29058	31816	30728	3.31	1.72	1.73	1.71
C_7 - Cotton + soybean(4:10)-Safflower	120853	82661	94825	91147	84574	41752	48929	45850	3.33	2.12	2.07	2.01
S.Em.±	2358	2218	1721	1214	2358	2218	1721	1214				
C.D.at 5 %	7266	6871	5303	3741	7266	6871	5303	3741				
B. Sub Plot -Nutrient Management												
F_1 - 100% RDF	108519	74387	78749	79023	73009	31954	32702	33394	3.08	1.82	1.73	1.75
F_2 - 50% N +100 % P and K applied through inorganic fertilizer + 50 % N through *Gliricidia*	101448	68914	77015	74821	65174	23769	27979	26703	2.81	1.55	1.59	1.57
S.Em.±	1212	1341	1341	737	1212		1341	1341	737			
C.D.at 5 %	3678	4067	4305	2272	3678		4067	4305	2272			
C. Interaction effect												
S.Em.±	3211	3547	3549	1951	3211		3547	3549	1951			
C.D.at 5 %	NS	NS	NS	NS	NS		NS	NS	NS			

Year wise Market prices Rs./qt

Crops	2013-14		*2015-16*		*2016-17*	
	Seed (Rs. q^{-1})	Stalk (Rs. q^{-1})	Seed (Rs. q^{-1})	Stalk (Rs. q^{-1})	Seed (Rs. q^{-1})	Stalk (Rs. q^{-1})
Seed Cotton	5200	100	4700	125	4150	125
Soybean Seed	3200	75	3550	100	2750	125
Chickpea Seed	2800	100	3200	125	3200	125
Linseed Seed	2800	100	4200	100	4200	125
Safflower Seed	4500	100	3200	100	3200	100

for producers to increase economic returns. Management of dynamic cropping systems will need to be based not only on single-year profit opportunities, but also on subsequent crop sequence effects. Maximum net returns was recorded at *american* improved cotton – mustard sequence followed by *american* improved cotton-wheat and *deshi* improved cotton-wheat sequence than sole cotton cropping system also reported by Venugopal *et al.*,(2000). Cotton + sorghum-ragi, followed by cotton-sunflower –ragi and cotton-maize–ragi sequences were more profitable and economically viable than sole cotton (Jagvir singh *et al.,* 2000).

iv. Rain water use efficiency:

Pooled results showed that, **c**otton + soybean (4:10) **-** safflower and sole soybean **-** safflower cropping system were being at par (2.91 and 2.82 kg $ha^{-1}mm^{-1}$) and recorded significantly higher water use efficiency than rest of the treatments. The rainwater use efficiency attended with cotton based sequence crop system was higher as compare to the RWUE attained with sole crops. This indicated higher resource use efficiency of both rainfall and soil moisture by the component crops during the crop season. This might be due to higher grain yields of both the crops than the amount of water used for biomass production. Consumptive use and rate of moisture use were higher in the sequence crop system than sole crop because both the crops absorbed more moisture during the crop period. Higher water use efficiency has been reported for maize-soybean and maize- mungbean (De and Singh, 1981) Tetarwal and Rana (2006) one row of mothbean in paired row of pearlmillet + and one row of greengram between paired rows of pigeonpea recorded higher water use efficiency over sole crop. Water use

Table.6 Rain water use efficiency as influenced by cropping pattern and nutrient management treatments

Treatments			Rain Water Use Effiicency (kg ha^{-1} mm^{-1})			
			2013-14	**2015-16**	**2016-17**	**Mean**
A. Main Plot (Cropping Pattern)						
C_1	-	Sole cotton	1.62	2.32	2.53	2.14
C_2	-	Sole soybean -Chickpea	2.43	2.60	2.15	2.38
C_3	-	Sole soybean -Linseed	1.96	1.88	1.88	1.88
C_4	-	Sole soybean - Safflower	2.72	2.64	2.81	2.82
C_5	-	Cotton + soybean (4:10)-Chickpea	2.73	2.89	2.60	2.68
C_6	-	Cotton + soybean(4:10)-Linseed	2.39	2.46	2.41	2.36
C_7	-	Cotton + soybean(4:10)-Safflower	2.75	2.93	3.03	2.91
		S.Em.±	0.11	0.08	0.06	0.04
		C.D.at 5 %	0.35	0.24	0.17	0.12
B. Sub Plot -Nutrient Management						
F_1	-	100 % RDF	2.48	2.63	2.52	2.52
F_2	-	50 % N +100 % P and K applied through inorganic fertilizer + 50 % N through *Gliricidia*	2.26	2.44	2.45	2.39
		S.Em.±	0.08	0.05	0.04	0.02
		C.D.at 5 %	NS	0.14	NS	0.07
		C. Interaction effect				
		S.Em.±	0.20	0.13	0.11	0.06
		C.D.at 5 %	NS	NS	NS	NS

efficiency recorded significantly higher in the treatment of 100% RDF than 50% N+100% P and K applied through inorganic fertilizer + 50% N through *Gliricidia* during the year 2015-16 and 2016-17 in pooled analysis (2.63 and 2.52). It might be due to higher seed cotton equivalent yield obtained under RDF. Behera *et al.*, (2002) reported that higher levels of nitrogen fertilizer to cotton recorded significantly higher water use efficiency than lower levels of nitrogen, 120 and 80 kg ha^{-1}. Reduction in nitrogen dose tended to decrease water use efficiency; it was partially because of marked decline in transpiring surface, less stomatal conductance and less extraction of available soil moisture in plant.

v. Sustainable yield index and sustainable value index

Sustainable yield index and value index recorded higher value in the treatments of Cotton + soybean (4:10)-safflower (0.94 and 0.85) followed by the treatment of sole soybean – sole safflower cropping system (0.90 and 0.72). In nutrient management treatment of 100% RDF recorded the higher sustainable yield index and sustainable value index (0.81 and 0.61). Same results

Table.7. Sustainability yield index & value index and system productivity & profitability as influenced by cropping pattern and nutrient management treatments

Treatments	Sustainable Yield Index (SYI)	Sustainable Value Index (SVI)	Total crop duration of sequence (days)	System Productivity (kg $ha^{-1}day^{-1}$)		System Profitability (Rs $ha^{-1}day^{-1}$)	
				Crop Productivity	System Productivity	Crop Profitability	System Profitabilty
A. Main Plot (Cropping Pattern)							
C_1 - Sole cotton	0.65	0.45	214	7.25	4.25	130.46	76.49
C_2 - Sole soybean -Chickpea	0.77	0.34	245	7.04	4.73	74.90	50.28
C_3 - Sole soybean -Linseed	0.61	0.19	253	5.38	3.73	42.75	29.63
C_4 - Sole soybean - Safflower	0.90	0.72	255	8.01	5.59	154.15	107.69
C_5 - Cotton + soybean (4:10)-Chickpea	0.87	0.71	245	7.93	5.32	152.53	102.38
C_6 - Cotton + soybean(4:10) -Linseed	0.76	0.57	253	6.75	4.68	121.45	84.19
C_7 - Cotton + soybean(4:10) -Safflower	0.94	0.85	255	8.25	5.76	179.80	125.62
S.Em.±				0.13	0.08	5.47	3.33
C.D.at 5 %				0.39	0.24	16.8	10.3
B. Sub Plot -Nutrient Management							
F_1 - 100 % RDF	0.81	0.61		7.43	5.00	136.28	91.49
F_2 - 50 % N +100 % P and K applied through inorganic fertilizer + 50 % N through *Gliricidia*	0.76	0.48		7.02	4.73	108.31	73.16
S.Em.±				0.07	0.05	3.24	2.02
C.D.at 5 %				0.23	0.14	9.99	6.23
C. Interaction effect							
S.Em.±				0.20	0.12	8.58	5.35
C.D.at 5 %				NS	NS	NS	NS

are coincide with work done by Wanjari *et al.,* (2004), Katkar *et al* (2012) and Srinivasarao *et al* (2012).

6. Chemical properties

The data in respect of pH and EC was found to be non-significant due to different cropping system as well as by the application of nutrient management treatments. One of the most important chemical properties of soil as a medium for plant growth is its pH. Effect of anion – cation imbalance in crop plants affects soil pH. Timsina *et al.,* (2001) reported a slight decrease in pH after three years of rice-wheat cropping system in Bangladesh. The above literature indicates differential response of cropping systems on soil pH. Soil environment and type of crops grown under different cropping systems play a significant role in relation to soil pH. Gawai (2003) reported that, reduction in soil pH, only due to microbial decomposition of organic manures.

In different cropping patterns, the maximum organic carbon content in soil was recorded in the treatments of sole soybean – chickpea and being at par with rest of the treatments and significantly superior than sole soybean –safflower treatments. Whereas, an application of different levels of fertilizers *i.e.* 100% RDF and 50% N +100% P and K applied through inorganic fertilizer + 50% N through *Gliricidia* was found at par (4.89 and 4.85 g kg^{-1}). Different cropping systems have different levels of uptake of plant nutrients. However, uptake of nutrients by same or similar cropping system over the years on the same land results in mining of similar nutrients from the soil affecting its fertility status. Sharma and Subehia (2003) also reported greater levels of soil organic carbon under integrated treatments of organic and inorganic combinations. Addition of fertilizer and integrated nutrients management generally results in build up of available nutrients, more so under rainfed conditions.

Table-8.Chemical properties of soil as influenced by the treatments of cropping pattern and nutrient management

Treatments	pH	EC	OC (g kg^{-1})	Av. Nutrients (kg ha^{-1})		
				N	P	K
A. Main Plot (Cropping Pattern)						
C_1 - Sole cotton	7.80	0.20	4.88	193.50	22.40	354.63
C_2 - Sole soybean -Chickpea	7.83	0.22	4.91	196.17	24.00	363.17
C_3 - Sole soybean -Linseed	7.84	0.21	4.85	193.17	23.79	361.90
C_4 - Sole soybean - Safflower	7.83	0.23	4.82	193.17	23.69	359.73
C_5 - Cotton + soybean (4:10)-Chickpea	7.83	0.22	4.90	196.33	23.92	363.77
C_6 - Cotton + soybean(4:10)-Linseed	7.84	0.21	4.85	192.17	23.63	361.29
C_7 - Cotton + soybean(4:10)-Safflower	7.82	0.23	4.84	193.00	23.47	359.95
S.Em.±	0.01	0.01	0.02	1.01	0.34	3.55
C.D.at 5 %	NS	NS	0.07	3.05	NS	8.68
B. Sub Plot -Nutrient Management						
F_1 - 100 % RDF	7.83	0.22	4.85	194.90	23.20	362.74
F_2 - 50 % N +100 % P and K applied through inorganic fertilizer 7.82 + 50 % N through *Gliricidia*	0.21	4.89	192.95	23.92	358.53	
S.Em. ±	0.01	0.01	0.01	0.76	0.27	2.08
C.D.at 5 %	NS	NS	0.04	2.35	NS	NS
C. Interaction effect						
S.Em.±	0.02	0.01	0.03	2.02	0.70	5.51
C.D.at 5 %	NS	NS	NS	NS	NS	NS
Initial Value	**7.81**	**0.21**	**4.71**	**182.11**	**19.8**	**341.6**

In our present investigation it was found that organic carbon increased with addition of 50 % N through g*liricidia* leaves. This is because of very good uptakes of nutrients by cotton and soybean crops. Available N status indicates that the N status of the soil was found to be high as compared to initial value (182.11 kg ha^{-1}). Maximum available N obtained was 196.33 and 196.17 kg ha^{-1} recorded in the treatment of sole soybean-chickpea and Cotton + soybean (4:10)-chickpea and being at par with the rest of the treatments. Treatments of soybean + chickpea and cotton +soybean (4:10)-chickpea recorded significantly higher available N than by sole cotton treatments, it means there was more mining of nutrients from directly available nutrient from fertilizer. Similar results have also been reported by Singh *et al.,* (2001).

An application of treatment 100 % RDF which was significantly higher over other treatment. The lowest value of available N (192.95 kg ha^{-1}) was observed in the INM plot. Hence, it is clear that application of chemical fertilizers increased the available N of soil, which may be attributed to mineralization of N.

Available P and K status of the surface soil did not shown the significant differences in cropping patterns and also in nutrients management treatments. The value of available phosphorus and potassium increased than initial value with application of RDF as well as by INM. Vertisols are generally rich in K content, and application of potassic fertilizers is not recommended in some pockets to these soils. Nevertheless, the importance of K in regulating and improving water functions in plant system and enabling the crop to withstand drought under rainfed conditions where intermittent dry spells are usual, cannot be undermined. Similar, observation was made by Bharadwaj *et al.* (1994).

Hence, it is recommended that, among the various treatments combination cotton + soybean (4:10)-safflower cropping sequence sown with tractor drawn seed drill with application of 100% RDF through inorganic (45:55:30 kg ha^{-1}NPK) applied in *kharif* season and 22:13.75:00 kg ha^{-1} NPK through inorganic fertilizer to safflower in *rabi* season recorded significantly higher cotton equivalent yield, net monetary returns, B:C ratio, RWUE, sustainable value and yield index, system productivity and profitability than rest of the treatment combinations.

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Effect of Irrigation Scheduling and Hydrogel on Growth, Yield, Economics, Water Requirement and Water Use Efficiency of Indian Mustard

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ABSTRACT

A field experiment with a objective of judging the optimum IW/CPE ratio for irrigation scheduling and optimum hydrogel dose for Indian mustard was conducted at College of Agriculture, Nagpur during *rabi* season of 2014-15 and 2015-16. The number of siliqua plant^{-1}, seed yield plant^{-1}, stover yield plant^{-1}, seed yield ha^{-1} (873.2 kg, 665.7 kg and pooled 769 kg), stover yield ha^{-1}, gross monetary returns (Rs 26633, 20304 and pooled 23469 ha^{-1}) and net monetary returns (Rs 14315, 7986 and pooled 11151 ha^{-1}) were maximum and significantly higher when irrigation applied at 0.8 IW/CPE ratio during both the year of experimentation and in pooled mean respectively and irrigation scheduled at 0.6 IW/CPE ratio was at par with 0.8 ratio. The test weight and harvest index were also higher at 0.8 IW/CPE ratio. The consumptive use was more (233.4, 222 and pooled 227.7 ha-mm) when irrigation applied at 0.8 IW/CPE ratio followed by 0.6 IW/CPE ratio. The water use efficiency was also significantly higher due to 0.8 IW/CPE ratio (3.78, 3.06 and pooled 3.42 kg ha-mm^{-1}) during 2014-15, 2015-16 and in pooled mean respectively.

Application of hydrogel @ 5 kg ha^{-1} recorded maximum and significantly higher, number of siliqua plant^{-1}, seed yield plant^{-1}, seed yield ha^{-1} and gross monetary returns during 2014-15, 2015-16 and in pooled mean, but the hydrogel dose @ 2.5 kg ha^{-1} was at par with it. However the stover yield plant^{-1} and stover yield ha^{-1} and net monetary returns were not influenced significantly by the hydrogel application. The consumptive use with hydrogel application at the rate of 5 kg ha^{-1} (184.9, 175 and pooled 180 ha-mm) was reduced compared to no use of hydrogel with significantly higher water use efficiency (4.07, 4.0 and pooled 4.04 kg/ha-mm) followed by 2.5 kg ha^{-1} hydrogel. The interaction effect was not significant.

The share of oilseeds is 14.1 per cent out of the total cropped area in India, rapeseed-mustard accounts for 3 per cent of it. India contributes 28.3 per cent acreage and 19.8 per cent production in world, (Kapila Shekhawat *et al.*, 2012). Water management warrants the need for deciding suitable irrigation scheduling which creates a favourable soil moisture environment for maximizing yield by conserving moisture, reducing weed growth and improving crop growth and yield promotional factors. Heavy soils are characterized as poor in drainage. Excess irrigation cause water logging condition which ultimately affects crop growth and further the crop yield. In the present day of scarcity, proper scheduling of irrigation play a vital role in economizing irrigation water and enhancing crop yield. Irrigation is an important factor which governs yield, consumptive use and water use efficiency of a crop.

Soils in arid and semiarid regions are poor in water holding capacity. The poor irrigation cause deficit soil moisture condition which ultimately affects crop growth and further the crop yield. This condition can be improved by using hydrogel. The application of hydrogel not only improve soil water holding capacity but also leads to efficient use of limited water for profitable crop production. Hydrogel absorbs water 350 times of its dry weight in water and gradually increases it. Low rate of application (1-1.5 kg per acre) exhibits absorbency at high temperature (40-50 ^{0}C), is suitable for semi arid and arid regions. Hydrogel is effective in soil for a minimum period of one crop season. It improves physical properties of the soil and the soil less media. It improves seed germination and the rate of seedling emergence. It reduces leaching of agro inputs such as herbicides and fertilizers. It reduces irrigation and fertigation requirement of crops. It also reduces nursery establishment period. Based on the farmers field trials and feedback obtained through interaction with licensees and the applicators, hydrogel application in all most all the tested crops, such as cereals, oilseeds, spices, flowers, etc has resulted significant improvement in the quality of

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agricultural produce. Hydrogel reduce the frequency of irrigation. Thus reducing drudgery in terms of labour involved in frequent irrigations .

In view of importance of irrigation water and unpredictable rainfall, water stress situation in mustard cultivation is of prime importance. Therefore, the experiment was planned with objectives to study the effect of hydrogel dose and IW/CPE ratio based irrigation scheduling on growth, yield, economics, water requirement and water use efficiency of mustard.

MATERIAL AND METHODS

A field experiment with a objective of judging the optimum IW/CPE ratio for irrigation scheduling and optimum hydrogel dose for Indian mustard was conducted at College of Agriculture, Nagpur during *rabi* season of 2014-15 and 2015-16. The experiment was laid out in split plot design replicated thrice with four irrigation schedule as main plot treatments viz., no irrigation, irrigation at 0.4 IW/CPE, at 0.6 IW/CPE and at 0.8 IW/CPE and three hydrogel doses as subplot treatments viz., no hydrogel, 2.5 kg hydrogel ha^{-1} and 5 kg hydrogel ha^{-1}. The soil was clayey in texture with normal pH(7.6), medium in soil organic carbon (5.36 g kg^{-1}), low in available nitrogen (219 kg ha^{-1}), very low in available P_2O_5 (12.82 kg ha^{-1}) and very high in available K_2O (370 kg ha^{-1}). The soil field capacity was 31.12% and permanent wilting point 14.15 % with bulk density of 1.5 g cm^{-3}. The effective rooting depth was 50 cm. The crop variety Pusa bold was sown with spacing of 30 cm × 10 cm. The observations were taken in respect of plant height, number of branches $plant^{-1}$ and total dry matter accumulation $plant^{-1}$ (g), number of siliquae $plant^{-1}$, number of seeds $siliquae^{-1}$, seed yield $plant^{-1}$ (g), test weight $plant^{-1}$ (g), seed yield (kg ha^{-1}) and stover yield (q ha^{-1}). The harvest index was also calculated. Five plants of mustard from each net plot were selected randomly, were labelled and used for various biometric observations on growth and post harvest studies. For the observation on dry matter accumulation $plant^{-1}$, two representative plants from each net plot were selected and used for the observation. The crop economics was estimated with the prevailing market prices and minimum support price of the crop. Water requirement was estimated from the observation of soil moisture content at sowing, at harvest and before each irrigation. The water economy (Rs/(kg/ha-mm) in terms of net monetary returns (Rs) per unit of water use efficiency (kg/ha-mm) was worked out.

RESULTS AND DISCUSSION

Effect of Irrigation schedule :

The growth attributes viz., plant height and number of branches $plant^{-1}$ were not influenced significantly by the irrigation schedule during both the year of investigation (Table 1). The number of siliqua $plant^{-1}$ (193.9 and 102.4), seed yield $plant^{-1}$ (3.8 and 4.1 g), stover yield $plant^{-1}$ (12.1 and 15.6 g), stover yield ha^{-1} (36.3 and 46.8 q/ha), were maximum and significantly higher when irrigation applied at 0.8 IW/CPE ratio and was at par with irrigation scheduled at 0.6 IW/CPE ratio during both the year of experimentation.

The seed yield ha^{-1} (873.2, 665.7 and 769 kg ha^{-1}), gross monetary returns (Rs 26633, 20304 and 23469 ha^{-1}), net monetary returns (Rs 14315, 7986 and 11151 ha^{-1}) during 2014-15, 2015-16 and in pooled results respectively were maximum and significantly higher when irrigation applied at 0.8 IW/CPE ratio during individual year as well as on pooled basis which in turn was at par with 0.8 IW/ CPE ratio. The benefit cost ratio (2.2, 1.62 and 1.91 during 2014-15, 2015-16 and in pooled respectively) were maximum due to irrigation applied at 0.8 IW/CPE ratio. The significant yield increase by 0.8 IW/CPE ratio might be attributed to higher growth parameter viz., plant height, dry matter, higher number of siliquae $plant^{-1}$, more test weight and higher yield $plant^{-1}$, more number of seeds $siliquae^{-1}$, which might be shown better due to less stress for availability of moisture to crop. DRMR (2015) also reported significant yield increase due to irrigation at 0.8 IW/CPE ratio over control. These results are also in conformity with the present investigation. The test weight during both the year was maximum due to irrigation at 0.8 IW/CPE ratio and harvest index was maximum during first year due to 0.8 ratio while during second year it was maximum due to 0.6 ratio.

The consumptive use was more (233.4, 222 and 227.7 ha-mm during 2014-15 and 2015-16 and in pooled respectively) when irrigation applied at 0.8 IW/CPE ratio closely followed by 0.6 IW/CPE. The water use efficiency

Table 1. Growth, yield attributes and stover yield ha^{-1} as influenced by irrigation scheduling with hydrogel

Treatments	Plant height (cm)		Number of branches $plant^{-1}$		Numberof siliqua $plant^{-1}$		Seed yield (g) $plant^{-1}$		Stover yield (g) $plant^{-1}$		Test weight (g/1000)		Stover yield (q ha^{-1})		HI %	
	2014 - 15	2015 -16	2014 -15	2015 -16	2014 -15	2015 -16	2014 -15	2015 -16	2014 -15	2015 -16	2014 -15	2015 -16	2014 -15	2015 -16	2014 -15	2015 -16
Mainplot - Irrigation (IW/CPE ratio)																
I_0 (control)	141.5	125.9	3.9	3.6	86.3	57.4	2.3	2.5	10.2	9.2	2.8	4.05	30.5	27.5	12.6	14.6
I_1 (0.4)	145.7	125.7	4.1	3.6	132.6	65.8	2.9	3.0	10.5	10.4	3.1	4.20	31.6	31.3	15.8	12.4
I_2 (0.6)	146.7	130.1	4.1	3.9	184.0	89.4	3.7	3.8	11.8	13.0	3.1	4.15	35.3	38.9	19.2	17.2
I_3 (0.8)	147.9	141.2	4.4	4.2	193.9	102.4	3.8	4.1	12.1	15.6	3.5	4.83	36.3	46.8	19.4	12.5
SE(m)±	2.61	4.63	0.18	0.14	3.67	5.83	0.08	0.11	0.15	0.94	-		0.46	2.82	-	-
CD (5%)	NS	NS	NS	NS	12.69	20.17	0.27	0.38	0.53	3.25	-		1.60	9.75	-	-
Subplot-Hydrogel																
Ho(control)	144.1	131.9	4.20	3.70	131.3	63.8	2.91	2.6	11.0	9.8	2.8	3.81	33.1	29.3	15.2	13.5
H_1 (2.5 kg ha^{-1})	145.2	132.4	4.07	3.85	155.9	72.8	3.29	3.5	11.3	12.0	3.3	4.33	33.8	35.9	17.5	14.4
H_2 (5.0 kg ha^{-1})	147.0	127.8	4.07	3.87	160.5	99.6	3.35	3.9	11.1	14.4	3.4	4.79	33.3	43.2	18.3	13.7
SE(m)±	1.80	3.53	0.11	0.16	3.40	3.75	0.07	0.19	0.21	0.89	-	-	0.63	2.68	-	-
CD (5%)	NS	NS	NS	NS	10.20	11.25	0.21	0.57	NS	2.68	-	-	NS	8.04	-	-
Interactions																
SE(m)±	3.60	7.06	0.22	0.33	6.81	7.51	0.14	0.38	0.42	1.79	-		1.26	5.37	-	-
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-		NS	NS	-	-

Table 2. Seed yield (ha^{-1}), economics and water economy as influenced by irrigation scheduling and hydrogel doses

Treatments	Seed yield (kg ha^{-1})			GMR (Rs ha^{-1})			NMR (Rs ha^{-1})			B:C ratio			WR (ha-mm)			WUE (Kg/ha-mm)			Water
	2014-15	2015-16	Pooled mean	2014-15	2015-16	Pooled mean	2014-15	2015-16	Pooled mean	2014-15	2015-16	Pooled mean	2014-15	2015-16	Pooled mean	2014-15	2015-16	Pooled mean	economy mean
Mainplot- Irrigation (IW/CPE ratio)																			
I_0 (control)	438	469	454	13370	14293	13832	1412	2335	1874	1.14	1.21	1.18	115.9	113	114.5	3.79	4.15	3.97	472
I_1 (0.4)	595	550	573	18149	16783	17466	6011	4645	5328	1.50	1.39	1.45	197.6	185	191.3	3.02	2.99	3.01	1770
I_2 (0.6)	838	643	743	25574	19774	22674	13256	7456	10356	2.14	1.65	1.90	231.5	214	222.8	3.65	3.05	3.35	3091
I_3 (0.8)	873	666	769	26633	20304	23469	14315	7986	11151	2.20	1.62	1.91	233.4	222	227.7	3.78	3.06	3.42	3261
SE(m) $\pm$	21.1	22.6	22	645	691	668	645	691	668	-	-	-	-	-	-	0.10	0.13	0.12	-
CD (5%)	73.1	78.3	76	2230	2389	2310	2230	2389	2310	-	-	-	-	-	-	0.36	0.44	0.40	-
Subplot-Hydrogel																			
Ho(Control)	595	458	527	18156	13984	16070	8803	4631	6717	1.93	1.49	1.71	205.9	192	199.0	2.91	2.48	2.70	2488
H_1 (2.5 kg ha^{-1})	716	602	659	21849	18373	20111	9626	6150	7888	1.78	1.50	1.64	192.9	183	188.0	3.70	3.45	3.58	2203
H_2 (5.0 kg ha^{-1})	747	689	718	22789	21008	21899	7816	6035	6926	1.52	1.40	1.46	184.9	175	180.0	4.07	4.00	4.04	1714
SE(m) $\pm$	20.0	30.7	25	611	936	774	611	936	774	-	-	-	-	-	-	0.09	0.16	0.13	-
CD (5%)	60.0	92.0	76	1831	2806	2319	NS	NS	NS	-	-	-	-	-	-	0.26	0.49	0.38	-
Interactions																			
SE(m) $\pm$	40.1	61.4	51	1222	1872	1547	1222	1872	1547	-	-	-	-	-	-	0.18	0.33	0.26	-
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-	-	-	-	-	NS	NS	NS	-

was maximum and significantly higher due to no irrigation treatment during both the year and in pooled mean followed by 0.8 IW/CPE ratio. The higher water use efficiency in no irrigation treatment might be due to less water requirement and comparatively more seed yield.

Effect of hydrogel doses :

The plant height and number of branches plant^{-1} were not influenced significantly by the hydrogel application during both the year. The number of siliqua plant^{-1} and seed yield plant^{-1} were maximum and significantly higher due to application of hydrogel @ 5 kg ha^{-1} during both the year of investigation, but the hydrogel dose @ 2.5 kg ha^{-1} was at par with it during year 2014-15. This might be due to better availability of moisture due to hydrogel. The stover yield plant^{-1} and stover yield ha^{-1} were maximum and significantly higher due to application of hydrogel @ 5 kg ha^{-1} in 2015-16 but were not influenced significantly by the hydrogel application during the year 2014-15. The test weight was also maximum due to application of hydrogel @ 5 kg ha^{-1} during both the year.

The seed yield (747, 689 and 718 kg ha^{-1}) and gross monetary returns (Rs 22789, 21008 and 21899 ha^{-1}) during 2014-15, 2015-16 and in pooled mean respectively were maximum and significantly higher due to application of hydrogel @ 5 kg ha^{-1}, but the hydrogel dose at the rate of 2.5 kg ha was at par with it. However the net monetary returns were not influenced significantly by the hydrogel application during both the year of experimentation. This might be due to higher cost of hydrogel application with comparatively lesser increment in yield as evidenced from the data. The benefit cost ratio was better with no hydrogel application during both year as well as in pooled mean. The consumptive use with hydrogel application at the rate of 5 kg ha^{-1} (184.9, 175 and 180 ha-mm) was reduced compared to no use of hydrogel (205.9, 192 and 199 ha-mm) with significantly higher water use efficiency (4.07, 4.0 and 4.04 kg/ha-mm) during 2014-15, 2015-16 and in pooled mean respectively followed by 2.5 kg ha^{-1} hydrogel. Tripathi *et al.* (1997) and Rana *et al.* (2001) reported more seed yield due to application of product similar to hydrogel i.e. *Jalshakti* @ 5 kg ha^{-1} and 2.5 kg ha^{-1} being at par as compared to control. DRMR (2015) Bharatpur also recorded similar results with hydrogel.

Interaction effect :

The interaction effect were not significant.

CONCLUSIONS

Thus from the two year data it can be concluded that irrigation may be applied at 0.8 or 0.6 IW/CPE ratio to Indian mustard under Vidarbha condition for significant yield increase, monetary returns and water economy (NMR/WUE). As regards to hydrogel @ 5 kg ha^{-1} increased the yield and gross monetary returns, reduced the water requirements and water economy but the net monetary returns was not influenced significanly. The water economy (Rs/(kg/ha-mm)) was also less.

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Effect of Planting Geometry and Fertilizer on Growth and Yield of Green Seed Coated Chickpea Under Irrigated Condition

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ABSTRACT

A field experiment was conducted during *rabi* season to study the crop geomtery and fertilizer levels for green seed coated chickpea varieties under protective irrigation. The treatment comprises of two varieties (AKGS 1 and AKG 9303-12), three spacing's (30x10 cm, 45x10 cm and 60x10 cm) andfour levels of fertilizers(Absolute control, 25:50 N:P_2O_5kg ha^{-1}, 30:60 N:P_2O_5kg ha^{-1}, 35:70 N:P_2O_5kg ha^{-1}. The experiment was laid out in a factorial randomized block design (FRBD) with three replications. Planting of chickpea varieties at 45x10 cm was found optimum. AKG9303-12 recorded higher crop growth and productivity over AKGS 1. Among fertilizer levels application of 35:70:00 NPK kg ha^{-1} recorded significantly higher seed yield over lower levels of fertilizers under imigation condition.

One of the main reasons of low yield of Chickpea is improper population. Too low and high plant population beyond a certain limit often adversely affects the crop yield. Number of plants per unit area influences plant size, yield components and ultimately the seed yield. Moreover, plant spacing in the field is also very important to facilitate aeration and light penetration in to plant canopy for optimizing rate of photosynthesis. There is very little information available on the relative contribution of various plant spacing towards yield and yield components and also their interaction. It is reported that row spacing of 45cm increased chickpea yield compared to 30 and 50cm spacing while others indicated that row spacing had no significant effect on seed yield (Panwar *et al*. 1980, Parihar 1996). Production and productivity of the crop is governed by environmental, genotypic trait of the crop and crop management. Determining appropriate crop geometry is therefore one of the most important crop management activities which improves the performance and productivity of plants. The planting density of chickpea in Maharashtra is 30×10 cm spacing for *desi* type chickpea and 45x10 cm for *kabuli* type, however, the green seed coat chickpea requires protective irrigation and has very meagre area under cultivation. Various studies indicated that chickpea varieties and population densities have significant effects on the growth as well as yield parameters.There is no varietal specific recommendation on the plantpopulation density of chickpeacultivars in Maharashtra; there is blanket recommendation of 30×10cm spacing. Therefore the objective of this study was to determine the effect of spacing and fertilizer levels on yield components and yield of green seed coated chickpea.

MATERIAL AND METHODS

A field experiment was conducted at the farm of the Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during rabi 2009-10. The texture of the experimental soil was clay loam. The soil pH was 7.72 with 5.20% organic carbon, available nitrogen 214 kg ha^{-1}, available P 21.05 kg ha^{-1}, available K_2O 343 kg ha^{-1}. The plot size was 4.0×3.6m. Fertilizer was applied in the form of urea and di-ammonium phosphate. Sowing was done10th October 2008 and harvesting on 25thJanuary 2009. Irrigation was done first as pre sowing, second at bud initiation stage and third at pod filling stage.

RESULTS AND DISCUSSION

Growth parameters:

The data revealed that cultivars differed significantly from one cultivar to another with respect to plant height. Significantly more plant height was recorded in variety AKG 9303-12 as compared to variety AKGS 1. Previously similar results have been reported by Kasole

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et al. (2005). In case of plant geometry increasing spacing recorded increase in plant height, however, significant increase was noticed up to wider spacing of 45x10 cm further increase in spacing did not reflect significant increase in plant height. Among fertility levels increase in plant height was recorded with increasing fertility level, however, significant increase in plant height was noticed up to 30:60:00 NPK kg/ha. Number of pods per plant is a key factor for determining the yield performance in leguminous plants as indicated by Rasul *et al.* (2012). Plant growth behavior of legume crops including chickpea can be determined by number of pods per plant. Branching is basically a genetic character and plays an important role in enhancing seed yieldvariety AKGS 1 had the lowest number of branches per plant while variety AKG 9303-12 had highest number of branches per plant.Varietal characteristics might have accounted for these significant differences observed in the branches, as they were grown under similar environment. This result is in agreement with the findings of Malek *et al.* (2012). With respect to spacing number of branches/plant influenced significantly, however, significant increase in branches was observed up to 45x10 cm spacing which in turn was found at par with 60x10 cm spacing.In contrast, the decreased number of branches in the narrower plant spacing might be due to the high competition for the resources and with the overlapped plant canopy, the crop might have been subjected to lower interception of sunlight which led to lower photo assimilation. This also indicated the plasticity response of plants to various plant spacing.Decreased in number of branches with the increase in density of chickpea was observed by (Togay *et al.* 2005).Among the fertility level number of branches increases with increase in fertilizer levels. Among various parameters contributing towards final yield of a crop, hundred-seed weight is of prime importance. A highly significant variation was observed between varieties for hundred-seed weight. Seed size is one of the most important yield related traits in chickpea crop and determines the final seed weight. The recorded variations for 100-seed weight could be attributed to small seed size. However, the main effect of spacing and fertilizer levels on hundred seed weight was not found significant.

Grain Yield:

Data pertaining to the seed yield (Table 1) elucidate a significant difference between varieties higher seed yield (1671 kg/ha) was obtained from AKG 9303-12 while lower seed yield (1392 kg ha^{-1}) was recorded from the variety AKGS 1. Among the varieties AKG 9303-12 recorded significantly higher seed yield by 16.69 % over AKGS 1. Seed yield of chickpea increased with increasing plant spacing. However, significantly higher yield was recorded at 45x10 cm over closer spacing and further increase in spacing did not influenced the seed yield significantly.These results are in line with the findings of Minhas *et al.* (2007) who stated that chickpeavariety differed significantly in their genetic potential and this potential was further widened with application of chemical fertilizers (NPK) in different combinations.Interaction effect between varieties and spacing and spacing,and fertilizer were found significant.

Table 1: Grain yield of chickpea as influenced by different treatments

Treatment	Seed yield(Kg/ha)
A. Variety	
V_1. AKGS 1	1392
V_2. AKG 9303-12	1671
S.Em ±	24.48
CD at 5%	69.69
B. Spacing	
S_1. 30 X 10 cm	1327
S_2. 45 X 10 cm	1570
S_3. 60 X 10 cm	1698
S.Em ±	29.99
CD at 5%	85.36
C. Fertilizer levels	
F_1. Absolute Control	1102
F_2. 25:50 N:P kg ha^{-1}	1533
F_3. 30:60 N:Pkg ha^{-1}	1666
F_4. 35:70 N:Pkg ha^{-1}	1825
S.Em±	34.62
CD at 5%	98.57
CV%	9.59

Table 2: Interaction between variety and spacing of chickpea as influenced by different treatments.

Variety	Spacing			
	30x10 cm	45x10 cm	60x10 cm	Mean
AKGS-1	1257	1398	1520	1392
AKG 9303-12	1398	1741	1875	1671
Mean	1327	1570	1698	
	Variety	Spacing	Variety x Spacing	
SEm$\pm$	24.48	29.99	42.41	
CD (5%)	69.69	85.36	120.72	

Table 3: Interaction between fertilizer and spacing of chickpea as influenced by different treatments.

FertilizerSpacing	ControlN:Pkgha^{-1}	25:50N:Pkgha^{-1}	30:60N:Pkgha^{-1}	35:70 N:Pkgha^{-1}	Mean
30x10 cm	1015	1311	1444	1541	1328
45x10 cm	1100	1591	1711	1877	1570
60x10 cm	1192	1698	1844	2058	1698
Mean	1102	1533	1666	1825	1532
	Fertilizer	Spacing	Fertilizer x Spacing		
S.Em$\pm$	34.62	29.99	42.41		
CD (5%)	98.57	85.36	120.72		

Table 4: Ancillary parameters of chickpea as influenced by different treatments

Treatment	Plant Height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}	Seed weight plant^{-1}	100-seed weight(g)
A. Variety					
V_1. AKGS1	48.19	5.97	46.11	46.93	17.41
V_2. AKG9303-12	48.54	6.44	50.65	48.19	19.58
S.Em ±	0.08	0.03	0.29	0.23	0.08
CD at 5%	0.23	0.09	0.85	0.67	0.24
B. Spacing					
S_1- 30 X 10 cm	48.11	6.06	47.38	46.72	18.47
S_2- 45 X 10 cm	48.32	6.24	47.94	47.64	18.49
S_3- 60 X 10 cm	48.63	6.33	49.81	48.32	18.66
S.Em ±	0.10	0.04	0.36	0.28	0.10
CD at 5%	0.28	0.11	1.04	0.82	NS
C. Fertilizer levels					
F_1. Absolute Control	47.61	5.59	45.59	44.98	18.39
F_2. 25:50 N:Pkg ha^{-1}	48.13	6.17	47.29	46.87	18.55
F_3. 30:60 N:Pkg ha^{-1}	48.67	6.43	49.44	48.28	18.60
F_4. 35:70 N:Pkg ha^{-1}	49.00	6.65	51.18	50.11	18.63
S.Em±	0.11	0.05	0.42	0.33	0.10
CD at 5%	0.33	0.13	1.20	0.95	NS
CV%	1.00	3.10	3.70	2.96	—

Interaction between Variety and spacing

There was significant variation in yield due to different spacing (Table 2).However, wider spacing of 60x10 cm was found very promising as it produced 1698 kg ha^{-1}yield. Currently recommended 30x10 cm spacing gave only 1327 kg ha^{-1} yield. It is further concluded that for getting highest yield of green seed coated chickpea sowing at spacing of 60x10 cm is more useful.

Interaction between spacing and fertilizer

The data mentioned in Table 3 recorded significantly higher grain yield (1825 kg ha^{-1}) with the of application of 35:70 N:P_2O_5 kg/ha over lower doses of fertilizer at all the spacing except at 30x10 cm which in turn was found at par with subsequent lower dose of fertilizer i.e.30:60 N:P_2O_5 kg/ha.

Correlation studies

The analysis of correlation (r) (Table 5) revealed positive and significant correlation of grain yield with grain weight/plant followed by number of branches/plant, number of pods/plant, plant height and 100-seed weight.

Table 5: Correlation studies between yield and yield attributes in chickpea

Yield attributes	'r' value
100 seed weight	+0.489**
Plant height at maturity	+0.829**
No. of pods $plant^{-1}$	+0.874**
No. of Branches $plant^{-1}$	+0.891**
Grain weight $plant^{-1}$	+0.904**

CONCLUSION

It is concluded that planting of checkpea varieties at 45 x 10 cm recorded higher yield while AKG 9303 registered highest seed yield under fertilizer dose of 35:70 N and P_2O_5 kg ha^{-1} under irrigation condition.

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Effect of Safed Musli + Pigeonpea Intercropping System on Growth, Yield and Root Quality of Safed Musli

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ABSTRACT

The present investigation entitled "Effect of safed musli + pigeonpea intercropping system on growth, yield and root quality of Safed musli" 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 soil fertility and evaluate the yield and quality of safed musli. The experiment was under Safed musli+ Pigeonpea intercropping with various row proportions 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. The experiment was laid in Randomized Block Design with four replications and six treatments. The intercropping of safed musli with pigeonpea at 3:1 row proportion was found superior for fresh root yield and dry root yield. Saponin content and yield was significantly influenced under Safed musli + Pigeonpea 3:1 row proportion. Protein content was significantly influenced under Safed musli + Pigeonpea 2:2 row proportion. However, the uptake of nutrients crop productivity and net monetary returns was recorded under safed musli pigeonpea intercropping 3:1 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, 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, 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. The economic part of the herb is root and is well known tonic and aphrodisiac drug given to cure general debility. Tribals in central India use leaves of this herb for vegetable purpose. The species of *Chlorophytum borivilanum* contains more saponin and good yielding potentials as compared to other species of Safed musli and therefore having commercial value. Due to its vast demand it is very costly and become a hot cake among medicinal plants.

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 investigations to study the soil

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fertility, productivity and economics of Safed musli and Pigeonpea intercropping under rainfed condition has worked out in present study.

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 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 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 RDF (25 kg N ha^{-1}). The treatment consists of 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

Growth parameters of safed musli

Number of leaves

On persual of data presented in Table 1, revealed that the significantly higher (12.25) number leaves were recorded under treatment T_2 *i.e.*,safed musli + pigeonpea intercropping in 3:1 ratio (T_2) which at par with treatment T_1 (2:1 row proportion). Similarly, during second year the highest no. of leaves (11.75) was recorded in treatment T_2 i. e safed musli + pigeonpea in 3:1 row proportion, while the lowest no. of leaves (10.25) were observed in treatment T_4 with safed musli+ pigeonpea in 1:2 row proportion.

The pooled data also indicated that highest (12.00) number of leaves were also recorded in treatment T_2 *i.e.*,safed musli + pigeonpea in 3:1 row proportion, whereas the minimum leaves (10.25) in treatment T_3 (10.25) *i.e.*,safed musli + pigeonpea in 2:2 row proportion followed by T5 (sole safed musli).

Leaf Area

Significantly higher leaf area (276.65 cm^2) was recorded under the treatment T_5 *i.e.*, sole safed musli which was at par with treatment T_2 i.e., safed musli + pigeonpea in 3:1 row proportion, while the lowest (268.00 cm^2) leaf area was recorded under safed musli + pigeonpea in 2:1 row proportion (T_1). Similarly, during second year (2016-17) the highest leaf area (278.00 cm^2) was recorded in treatment T_5 (sole safed musli).

The pooled data indicated that the leaf area significantly influenced due to intercropping in treatment T_5 (277.32 cm^2) followed by treatment T_2 (271.70 cm^2).

Leaf Area Index

The higher leaf area index (0.718) was recorded under the treatment T_5 *i.e.*, sole safed musli which at par with remaining all treatments of safed musli + pigeonpea intercropping. While, the lowest leaf area index (0.643) was registered under T_1 *i.e.*, safed musli + pigeonpea in 2:1 row proportion.

During second year the leaf area index varied from 0.645 to 0.720. The highest (0.720) leaf area index was observed in treatment T_5 *i.e.*, sole safed musli which was at par with treatment T_3 (2:2 row proportion) and T_4 (1:2 row proportion). The pooled data generated on leaf area index was highest (0.719) and lowest (0.644) in treatment T_5 and T_1 respectively.

Yield contributing character and yield

Number of Roots

On persual of data presented in Table 2, revealed that 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. Further it was noticed that 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 at par with treatment T_5 (sole safed musli). Pooled data indicated that the application of safed

Table 1: Number of leaves, leaf area and leaf area index of safed musli as influenced by safed musli + pigeonpea intercropping system

Treatments	No. of leaves Plant^{-1}			Leaf Area (cm^2)			Leaf Area Index		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1 - Safed musli + Pigeonpea (2:1)	10.50	10.20	10.35	268.00	270.60	269.30	0.643	0.645	0.644
T_2 - Safed musli + Pigeonpea (3:1)	12.25	11.75	12.00	271.25	272.30	271.70	0.650	0.651	0.653
T_3 - Safed musli + Pigeonpea (2:2)	10.50	10.00	10.25	270.00	268.0	269.00	0.680	0.682	0.681
T_4 - Safed musli + Pigeonpea (1:2)	11.00	10.25	10.62	269.50	270.55	270.02	0.688	0.689	0.680
T_5 - Sole Safed musli	10.00	10.50	10.25	276.65	278.00	277.32	0.718	0.720	0.719
T_6 - Sole Pigeonpea	-	-	-	-	-	-	-	-	-
SE (m) ±	0.71	0.65	0.65	2.84	2.80	3.50	-	-	-
CD at 5 %	2.14	1.02	1.97	8.56	8.60	7.50	-	-	-

Table 2: Number of roots, Safed musli fresh root yield (q ha$^{-1)}$ and Safed musli dry root yield (q ha$^{-1)}$ of safed musli as influenced by safed musli + pigeonpea intercropping system

Treatments	No. of Roots plant^{-1}			Safed musli fresh root yield (q ha$^{-1)}$			Safed musli dry root yield (tons ha$^{-1)}$		
	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	24.43	22.54	23.48	4.15	3.84	3.99
T_2 - Safed musli + Pigeonpea (3:1)	9.25	10.20	9.70	33.40	30.44	31.92	5.67	5.17	5.42
T_3 - Safed musli + Pigeonpea (2:2)	8.30	8.50	8.25	22.55	21.60	22.07	3.83	3.67	3.75
T_4 - Safed musli + Pigeonpea (1:2)	7.75	7.80	7.78	13.31	12.38	12.84	2.26	2.10	2.18
T_5 - Sole Safed musli	8.75	9.00	8.87	32.14	30.22	31.18	5.46	5.13	5.30
T_6 - Sole Pigeonpea	-	-	-	-	-	-	-	-	-
SE (m) ±	0.39	0.41	0.31	0.68	0.72	0.46	0.07	0.09	0.006
CD at 5%	1.14	1.20	0.93	2.00	2.10	1.40	0.23	0.30	0.15

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). These results are in close agreement with Wankhade *et al.*, (2004) and Anonymous (2015).

Safed musli fresh root yield (q ha$^{-1)}$

The fresh root yield (q ha$^{-1)}$ significantly influenced by different intercropping proportion, 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, the highest fresh root yield (30.44 q ha^{-1}) was recorded in T_2 (safed musli + pigeonpea in 3:1 row proportion) which at par with T_5 (sole afed 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. Pooled data also indicated that highest fresh yield with T_2 (31.92 q ha^{-1}) followed by treatment T_5 (31.18 q ha^{-1}). Findings are in close accordance with the result reported by Wankhade *et al.* (2004), Shivankar *et al*. (2015) and Anonymous (2015).

Safed musli dry root yield (q ha$^{-1)}$

The dry root yield per hecare was influenced by intercropping with various row propotion of safed musli + pigeonpea. The dry root yield q. ha^{-1} was also 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 indicated that significantly higher (5.42 q ha^{-1}) dry yield was recorded in treatment T_2 followed by treatment T_5 (5.30 q ha^{-1}).

The lowest fresh and dry root yield was recorded under treatment T_4 *i.e.*, safed musli + pigeonpea in 1:2 row proportion. Significantly highest root yield obtained with the intercropping of safed musli + pigeon pea in 3:1 row

Table 3: Dry matter accumulation and yield of safed musli as influenced by safed musli + pigeonpea intercropping system

Treatments	Dry matter accumulation plant^{-1} (g)			Dry matter Yield (kg ha^{-1})		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1 - Safed musli + Pigeonpea (2:1)	0.98	0.99	0.98	88.0	89.0	88.0
T_2 - Safed musli + Pigeonpea (3:1)	1.12	1.10	1.11	128.0	118.0	123.0
T_3 - Safed musli + Pigeonpea (2:2)	0.98	0.90	0.94	88.0	89.0	88.0
T_4 - Safed musli + Pigeonpea (1:2)	0.86	0.80	0.83	79.0	66.0	72.0
T_5 - Sole Safed musli	1.32	1.30	1.31	152.0	156.0	154.0
T_6 - Sole Pigeonpea	-	-	-	-	-	-
SE (m) ±	0.10	0.20	0.15	1.2	1.0	1.3
CD at 5%	0.31	0.21	0.26	7.5	8.1	5.3

Table 4 : Safed musli root quality as influenced by safed musli + pigeonpea intercropping system

Treatments	Saponin content (%)			Saponin yield (kg ha^{-1})			Protein content (%)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1 - Safed musli + Pigeonpea (2:1)	6.38	6.53	6.45	26.47	25.07	25.77	10.41	9.97	10.19
T_2 - Safed musli + Pigeonpea (3:1)	6.92	6.94	6.93	39.23	35.87	37.55	10.77	10.00	10.39
T_3 - Safed musli + Pigeonpea (2:2)	5.98	5.99	5.99	22.90	21.98	22.44	11.22	11.09	11.16
T_4 - Safed musli + Pigeonpea (1:2)	6.64	6.67	6.65	15.00	14.00	14.50	10.94	10.83	10.88
T_5 - Sole Safed musli	6.71	6.76	6.74	36.63	34.67	35.65	10.84	10.39	10.61
T_6 - Sole Pigeonpea	-	-	-	-	-	-	-	-	-
SE (m) ±	0.20	0.19	0.096	0.90	0.91	0.56	0.40	0.37	0.18
CD at 5%	0.61	0.59	0.29	2.70	2.74	1.70	NS	0.75	0.56

might be due to favorable partial shade effect which recorded in better crop growth and ultimately the root yield. These results are supported by the findings of Wankhade *et al*. (2004), who has recorded higher yield of safed musli with the application of FYM 20 t with various nitrogen levels.

Dry matter accumulation

On persual of data presented in Table 3, revealed that the dry matter accumulation of safed musli (g plant^{-1} and kg ha^{-1}) was ranged from 0.86 to 1.32 and 0.80 to 1.30 g plant^{-1} during year 2015-16 and 2016-17 respectively.

Further, highest (1.32 g plant^{-1}) dry matter accumulation was recorded in treatment T_5 with sole safed musli which was at par with treatment T_2 (3:1 row proportion) during first year. Safed musli + pigeonpea in 1:2 row proportion (T_4) was recorded lowest (0.86 g plant$^{-1)}$ dry matter accumulation. Similar trend was also observed during second year. Pooled result indicated that highest dry matter accumulation g plant^{-1} was recorded in treatment T_5 under sole safed musli followed by treatment T_2 under safed musli + pigeonpea in 3:1 row proportion.

Dry matter yield kg ha^{-1}

The dry matter yield (kg ha^{-1}) was ranged from 79.0 to 152.0 and 66.0 to 156.0 kg ha^{-1} during 2015-16 and 2016-17 respectively. Highest (152.0 kg ha^{-1}) dry matter yield was recorded in treatment T_5 under sole safed musli during first year. During second year 2016-17 highest dry matter yield (156.0 kg ha^{-1}) was recorded in treatment T_5 under sole safed musli. Lowest (66.0 kg ha^{-1}) dry matter yield was recorded in treatment T_4 under safed musli + pigeonpea in 1:2 row proportion.

Pooled result indicated that highest (154.0 kg ha^{-1}) dry matter yield was recorded in treatment T_5 under sole safed musli followed by treatment T_2 under safed musli + pigeonpea in 3:1 row proportion.

Quality parameters of safed musli root

Saponin content (%)

The saponin content of Safed musli under different row proportions varied from 5.98 to 6.92% and 5.99 to 6.94 per cent during both years respectively. Further it was observed that saponin content was significantly influenced with treatment of Safed musli + Pigeonpea in 3:1 row proportion (T_2) which was at par with rest of the treatments except T_3 *i.e.,* Safed musli + Pigeonpea in 2:2 row proportion. The results on saponin content during second year (2016-17) also showed similar trend. However, the pooled data indicated that significantly highest saponin content was observed under Safed musli + Pigeonpea in 3:1 row proportion (T_2) which was at par with treatment T_5 (Sole Safed musli) and T_4 (Safed musli + Pigeonpea in 1:2 row proportion).

Saponin yield

The data regarding saponin yield as influenced by different row proportions varied from 15.00 to 39.23 kg ha^{-1} and 14.00 and 35.87 kg ha^{-1} in year 2015-16 and 2016-17 respectively. Further, it was observed that significantly highest saponin yield (39.23 kg ha^{-1}) was observed in treatment T_2 *i.e.,* Safed musli + Pigeonpea in 3:1 row proportion followed by T_5 (Sole Safed musli). The lowest saponin yield (15.00 kg ha^{-1}) was observed in T_4 with Safed musli + Pigeonpea in 1:2 row proportion. Whereas, results during second year (2016-17) revealed that significant highest saponin yield (35.87 kg ha^{-1}) was observed with treatment T^2 with Safed musli + Pigeonpea in 1:2 row proportion which was at par with treatment T^5 *i.e.,* sole safed musli. However pooled mean showed that the Safed musli + Pigeonpea in 3:1 row proportion (T_2) was found superior overall treatments to recorded highest saponin yield (37.55 kg ha^{-1}) followed by Sole Safed musli (T_5).

Protein content (%)

The data on protein content of safed musli are presented in Table 4, it was ranged from 10.41 to 11.22 per cent and 9.97 to 11.09% during 2015-16 and 2016-17 respectively. The protein content was not significantly influenced in first year study, however, numerically highest content was noted in treatment T_3 (2:2 row proportion). The second year results revealed that significantly highest protein content of safed musli (11.09 %) was recorded under treatment T_3 with safed musli + pigeonpea in 2:2 row proportion which was at par with treatment T_4 (1:2 row proportion) and treatment T_5 (sole safed musli). The lowest protein content was observed in treatment T_1 with the safed musli + pigeonpea in 2:1 row proportion (9.97%).

Pooled result indicated that significantly highest (11.16 %) protein content was recorded with treatment T_3 (2:2 row proportion) which was at par with T_4 safed musli + pigeonpea in 1:2 row proportion and T_5 (sole safed musli). Results are in agreement with the findings of Wankhade *et al.*, (2004).

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Effect of Zinc Sulphate for Enhancing Growth and Yield in Greengram-Chickpea Sequence

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ABSTRACT

A field experiment was conducted during the *kharif* 2016 at Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola to determine the direct as well as residual effect of zinc sulphate on performance of greengram–chickpea cropping system under rainfed conditions. Significantly higher grain yield of greengram were observed with application of zinc sulphate over RDF alone and absolute control. Application of zinc sulphate @ 25 kg/ha without or with foliar spray of zinc sulphate (0.5%) over remaining levels. Plant height, pods/plant and grain weight/plant of greengram was largely influenced due to zinc sulphate over control. Under residual effect of zinc sulphate production of chickpea were increased significantly across the zinc sulphate levels.

Greengram also plays an important role in sustaining soil fertility by improving soil physical properties and fixing atmospheric nitrogen. It is a drought tolerant crop and suitable for dry land farming and predominantly used as an intercrop with other crops. It is mostly consumed in Southern India. Considering its nutritional value and price, it is necessary to raise its production level and nutritional quality. The average yield is quite low which require attention of the crop expert. Among various factor, judicious use of fertilizer is of prime importance. Micronutrients play an important role in increasing yield of pulses and oilseed through their effects on plant growth itself and on the nitrogen fixing symbiotic process. Periodic assessment of soil test data also suggests that zinc deficiency in soils of India is likely to increase from 49 to 63% by the year 2025 as most of the marginal soils brought under cultivation are showing zinc deficiency (Singh, 2006). Increased use of high-analysis fertilizer and less or no use of organic manure and continuous multiple cropping with fertilizer-responsive varieties of crops have accentuated the depletion of their reserves in the soil, often leading to significant responses to their application. Zinc deficiency reduces not only the grain yield, but also the nutritional quality of grain and ultimately nutritional quality of human diet.

Zinc plays an important role in formation of chlorophyll and growth hormones and is associated with the uptake of water. Zinc promotes nodulation and nitrogen fixation in leguminous crops (Demeterio *et al;* 1972). Besides this, Zinc plays a regulatory role in the intake and efficient use of water by plants. It acts as an activator of several dehydrogenase enzymes in plants and is directly involved in the biosynthesis of growth substances such as auxin (like, tryptophane synthesis, tryptamine metabolism) which produces more plant cells (Devlin *et al.*, 1983); stabilization of ribosomal fractions (Obata *et al.,* 1999). It enhances photosynthesis at early growth of plants, improves nitrogen fixation, grain protein and yields of mungbean plants (Krishna, 1995). Zn also stimulates resistance for dry and hot weather, bacterial and fungal diseases and ribosomal fraction in the plants. In view of the above present investigation was undertaken to enhance the productivity and quality of greengram produce through zinc application.

MATERIALS AND METHODS

A field experiment was conducted at the farm of the Pulses Research Unit, Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *Kharif* 2016. The texture of the experimental soil was clay loam. The soil pH was 7.95 with 0.4 per cent organic carbon low available nitrogen(218 kg ha^{-1}), medium available P (20.10 kg ha^{-1}), high available K_2O 310 kg ha^{-1}. The treatment comprises of Absolute control, RDF alone (20:40 $N:P_2O_5$ kg ha^{-1}) three levels of zinc (15, 20 and 25 kg ha^{-1}) without and with foliar spray of zinc 0.5 per cent and foliar spray of zinc sulphate 0.5 per cent at pod filling stage alone. The experiment was laid out in a randomized block design (RBD) with three replications. The plot size was 4.0 × 4.5 m. Fertilizer were applied in the form of urea and di-ammonium phosphate except in absolute control. Sowing of greengram was done on 18 June 2016 and harvesting on 9 September 2016 and

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Table 1: Effect of different treatment on growth parameters and yield of Greengram-Chickpea sequence

Treatment		Grain yield (kg ha^{-1})	
		Greengram	Chickpea
1	Absolute Control	548	1295
2	RDF (20:40 N:P_2O_5 kg/ha)	964	1556
3	RDF + $ZnSO_4$ @ 15 kg/ha	1305	1628
4	RDF + $ZnSO_4$ @ 20 kg/ha	1341	1645
5	RDF + $ZnSO_4$ @ 25 kg/ha	1408	1668
6	RDF + $ZnSO_4$ @ 15 kg/ha + FS of $ZnSO_4$ @ 0.5%	1337	1650
7	RDF + $ZnSO_4$ @ 20 kg/ha + FS of $ZnSO_4$ @ 0.5%	1367	1671
8	RDF + $ZnSO_4$ @ 25 kg/ha + FS of $ZnSO_4$ @ 0.5%	1413	1690
9	RDF + FS of $ZnSO_4$ @ 0.5%	998	1594
	CD at 5%	40.46	42.03

1) FS- Foliar Spray of ZnSO4 @ 0.5% at pod filling stage
2) Soil application of ZnSO4 is given to greengram only.

Table 2. Chlorophyll a, b and carotenoid (mg g^{-1} dry weight) in the leaves of mungbean greengram at 45 DAS as influenced by different treatments.

Treatment		Chl a	Chl b	Total chl	Carotenoid
			(mg g^{-1} dry weight)		
1	Absolute Control	13.69	8.88	20.21	0.360
2	RDF (20:40 N:P_2O_5 kg/ha)	22.50	13.47	32.13	0.615
3	RDF + $ZnSO_4$ @ 15 kg/ha	23.15	13.76	34.22	0.599
4	RDF + $ZnSO_4$ @ 20 kg/ha	22.05	12.98	32.27	0.580
5	RDF + $ZnSO_4$ @ 25 kg/ha	21.57	11.13	30.40	0.578
6	RDF + $ZnSO_4$ @ 15 kg/ha + FS of $ZnSO_4$ @ 0.5%	23.41	12.39	29.51	0.583
7	RDF + $ZnSO_4$ @ 20 kg/ha + FS of $ZnSO_4$ @ 0.5%	21.53	10.67	26.35	0.576
8	RDF + $ZnSO_4$ @ 25 kg/ha + FS of $ZnSO_4$ @ 0.5%	21.03	10.07	25.65	0.575
9	RDF + FS of $ZnSO_4$ @ 0.5%	21.64	12.83	30.77	0.562

Table 3. Ancillary parameters of greengram as influenced by different treatments

Treatment		Plant height (cm)	Pods $plant^{-1}$	Seed weight $Plant^{-1}$(g)	100-seed weight(g)
1	Absolute Control	34.06	15.67	4.11	4.152
2	RDF (20:40 N:P_2O_5 kg/ha)	43.54	18.73	4.91	4.175
3	RDF + $ZnSO_4$ @ 15 kg/ha	52.73	19.00	4.73	4.192
4	RDF + $ZnSO_4$ @ 20 kg/ha	55.59	18.33	4.88	4.205
5	RDF + $ZnSO_4$ @ 25 kg/ha	59.93	21.93	5.59	4.268
6	RDF + $ZnSO_4$ @ 15 kg/ha + FS of $ZnSO_4$ @ 0.5%	53.07	18.93	4.34	4.187
7	RDF + $ZnSO_4$ @ 20 kg/ha + FS of $ZnSO_4$ @ 0.5%	56.36	19.13	5.18	4.213
8	RDF + $ZnSO_4$ @ 25 kg/ha + FS of $ZnSO_4$ @ 0.5%	60.52	23.00	5.95	4.350
9	RDF + FS of $ZnSO_4$ @ 0.5%	45.27	19.00	4.37	4.323
	CD at 5%	7.55	2.08	0.74	NS

sowing of chickpea on 10 October 2016 and harvested on 22 January 2017.

The greengram was sown at row spacing of 45 cm and chickpea at 30 cm. Recommended basal dose of nitrogen (20 kg N ha^{-1}) and phosphorus (40 kg P_2O_5 ha^{-1}) and zinc sulphate was applied to greengram only and nitrogen (20 kg N/ha) and phosphorus (40 kg P_2O_5 ha^{-1}) to chickpea through urea and di-ammonium phosphate excluding absolute control. The procedure for chlorophyll determination was based on the work of Mac. Kinney (1941), on the absorption of light by aqueous acetone (80%) extracts of chlorophyll. Organic solvent, 4:1 acetone alcohol was used.

RESULTS AND DISCUSSION

Greengram yield was significantly increased due to application of zinc sulphate with or without foliar spray of zinc sulphate. Highest grain yield was obtained from application of 25 kg zinc sulphate ha^{-1} with or without foliar spray of zinc sulphate at pod filling stage which was significantly higher over lower level of zinc sulphate and RDF alone (T_2) or with foliar spray of zinc sulphate (T_9). The lowest seed yield was recorded with control. It was observed that yield increased gradually with the increase of Zinc sulphate level up to 25 kg ha^{-1}. The chlorophyll a, b, total and carotenoid pigment was higher with application of zinc sulphate with or without foliar spray of zinc sulphate. No significant variation was observed in case of 100-seed weight. Seed weight and number of pods per plant increased with the increase of zinc sulphate with or without foliar spray of zinc sulphate. Chlorophyll pigments (chlorophyll a, b and carotenoid) showed better result due to application of different levels of zinc sulphate with or without foliar spray of zinc sulphate over RDF alone and absolute control (Table 2). Similar results are obtained by Malik *et al*. (2015). Plant height, number of pods $plant^{-1}$ and seed weight $plant^{-1}$ were significantly influenced excepting 100-seed weight due to different levels of zinc sulphate with or without foliar spray of zinc sulphate over RDF alone and absolute control (Table 3).

The grain yield of chickpea was significantly influenced due to residual effect of zinc sulphate applied to geengram. There was significant increase in yield with increasing levels of residual zinc sulphate (Table 1).

CONCLUSION

It is concluded that the soil application of $ZnSO_4$ @ 25 kg ha^{-1} along with RDF with foliar spray of $ZnSO_4$ @ 0.50 per cent at pod filling stage recorded higher green gram grain yield and residual effect of zinc also recorded higher seed yield of chick pea.

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Effect of Potassium on Productivity of Rice in Vertisols of Central India

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ABSTRACT

The experiment on farmer's field was conducted to study the effect of potassium application on productivity of rice (cv Pusa Basmati-1) in Vertisols during kharif 2016-17 and 2017-18. There were four treatments with graded doses of potassium (K) viz., K_0, $K_{40,}$ K_{80} and K_{FP} (farmers' practice) with five replications in randomized block design. Results indicated that application of K has significant effect on yield and yield attributes of rice. Increase in number of tillers, filled grains per panicle, test weight, stover and grain yield of rice was recorded with K_{80} (96 kg K_2O ha^{-1}) followed by K_{40} (48 kg K_2O ha^{-1}) over control (0 kg K_2O/ha) and farmers' practice (without K).The magnitude of response in rice yield was more withK_{80} (96 kg K_2O ha^{-1}) compared to K_{40} (48 kg K_2O ha^{-1}) that indicates higher dose of K is essential to maximize the crop productivity of rice in Vertisols.

Rice is grown in about 114 countries on around 158.4 million ha area and 701.9 million metric tonnes production during 2015-16 in the world (Anonymous, 2015[b]). Amongst the rice growing countries, China and India contributes more than half of the total production. Thus, rice is staple food and contributes to a great extent in livelihood security of the farmers and almost every household in India. In our country, rice contributes to 30.9 per cent in terms of area and 39.5 per cent production to the food basket as food grain in the country (Anonymous, 2015[a]). In order to safeguard, the food security in India, it is important to raise the yield levels of rice. Rice being an important staple food crop of India extensively grown across the country. In order to enhance the productivity and production high yielding varieties were introduced along with high analysis fertilizer such as nitrogen (N) and phosphorus (P)that led to extra mining of native potassium (K) from soil. That eventually resulted in decline of soil available K-status in many soils including Vertisols and associated soils. Data emanated from long-term experiments in India indicated that there is response to applied K by several crops. In general, majority of farmers in our country do not apply K, and even if K is applied, it is in a meager quantity. However, average K-removalby majority of field crops is very large to the extent of 120-130 kg ha^{-1}by single crop (Singh and Wanjari, 2012) and thus, hidden hunger of potassium was observed in many crops including rice grown on various soils including red soils, sandy light textured soils, degraded lands and shallow black soils (Srinivasarao *et al.*, 2011). Under this situation K could pose a threat not only to sustainability but also to food security as whole. Vertisols are although considered to be rich in K status but crops started showing response gradually to applied K may be due to larger removal of K from soils than the applied (Singh and Wanjari, 2012).The results emerged from long-term fertilizer experiments also opined that there is gradual response to K in Vertisols and associated soils even though soils are having K content more than the yardstick (280 kg K/ha). Thus, in the present study an attempt has been made to study the response of rice to applied K in Vertisols with varying K content in major soils of central India.

MATERIALS AND METHODS

The experiment was conducted during *kharif* 2016-17 and 2017-18 on farmers' field at Khamkheda (23°23'N and 77°25' at 489 m above mean sea level) near Bhopal (Madhya Pradesh, India) to study the effect of variable doses of K application on yield and yield attributing parameters of rice. The four treatments were imposed on five farmers's field and considered one farmer as one replication. The experiment was laid out in randomized block design (RBD). The treatment comprised of K_0 (0 kg K_2O ha^{-1}), K_{40} (48 kg K_2O ha^{-1}); K_{80}(96 kg K_2O ha^{-1}) and K_{FP} (farmers' practice). The seed of rice @ 25 kg ha^{-1} (cv. Pusa Basmati-1) was sown in the nursery and transplanted after 30 DAS in the bunded field at the spacing of 20 cm x 25 cm. Recommended doses of fertilizers

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@ N 120 kg ha^{-1}, P_2O_5 60 kg ha^{-1}, and $ZnSO_4$ @ 10 kg ha^{-1} were uniformly applied in the form of urea, diammonium phosphate (DAP) and zinc sulphate, respectively. The average nutrients applied in farmers' practice were only N and P_2O_5 @112 and 62 kg per ha, respectively. Soil samples were collected from farmer's field and analyzed for pH, electrical conductivity, available N, P and K as per standard method. Briefly, pH was determined by potentiometry using 1:2.5 soil water suspensions as described by Jackson, 1967. Organic carbon was determined by Walkley and Black's rapid titration method (1934) as described by Nelson and Sommers (1982). The available N in soil was determined by alkaline potassium permanganate method as described by Subbiah and Asija (1956). Soil available P was determined by using 0.5M $NaHCO_3$ (pH 8.5) solution (Olsen extractant). Briefly, Darco-G-60 soluble P was used to absorb the dispersed organic matter and make the filtrate colorless for further colorimetric analysis (Watanabe and Olsen, 1965). Soil available K was extracted by shaking with neutral normal ammonium acetate for 5 minute (Hanway and Heidel, 1952) and K in the extract was estimated by flame photometer. Soils were clay loam with alkaline soil reaction (pH 7.6), EC (0.19 dS m^{-1}), organic carbon (6.2 g kg^{-1}), available N (259 kg ha^{-1}), available P (30.3 kg ha^{-1}) and available K ranged from 338 to 410 kg ha^{-1}. The intercultural operations including plant protection measures were carried out as per recommendation and package of practices.The yield and yield attributes for rice were recorded at harvest of crop.

RESULTS AND DISCUSSION

Application of potassium has significant effect on yield and yield attributes of rice. Data indicated that K application has improved the number of tillers, filled grains per panicle and test weight in rice (Table 1).

Yield Attributes

No. of Tillers: The mean number of tillers varied from 190 to 199 and 203 to 226 m^{-2} during 2016-17 and 2017-18, respectively with mean value of 197 to 212 m^{-2}. The maximum tillers were recorded with the application of K at 90 kg ha^{-1}. The tillers in rice were maximum with the application of 80 kg K ha^{-1} (K_{80}) followed by 40 kg K ha^{-1} (K_{40}) and both the treatments were significantly higher than K_0 and K_{FP}. However, K_{80} and K_{40} treatments found at par in this respect.

Grains per panicle: The number of filled grains per panicle varied from 157 to 192. The number of grains were significantly higher with the application of 90 kg K /ha in both the years. The filled grains were maximum with K_{80} followed by K_{40} and both the treatments were significantly higher than K_0 and K_{FP}. The increase in this yield attribute resulted in higher grain and stover yield of rice in respective treatments.

Test weight: The test weight varied from 21.4 to 22.3 g. The test weight was significantly higher with the K application at 90 kg K/ha in both the years. The test weight were maximum with K_{80} followed by K_{40} and both the treatments were significantly higher than K_0 and K_{FP}. The increase in test of seed is the indicator of translocation of photosynthates to the grains. This indicates K application may have synergistic effect and as a result increased grain filling and size of grain.

Crop Productivity

Grain and stover yield: An increase in K doses resulted in concomitant increase in grain, stover yield and test weight. Yield attributes of rice primarily tillers, filled grains and test weight improved significantly over no K application as well as farmers' practice. This resulted in increase in grain and stover yield of rice (Table 2). The yield and yield attributes were in order of K_{80} (96 kg K_2O ha^{-1}) followed byK_{40} (48 kg K_2O ha^{-1}), K_0 (0 kg K_2O ha^{-1}) and K_{FP}(Farmers' practice). It implies that K along with N and P enhanced rice yield in Vertisols during both the years. Even though highest yield was recorded with an application of K_{80} (96 kg K_2O ha^{-1}) but was found at par with K dose of K_{40} (48 kg K_2O ha^{-1}) in the first year indicating gradual response to K application in Vertisols. However, in second year K_{80} recorded significantly high yield compared to all other treatments. Thus, magnitude of response was higher at higher K doses indicating response to relatively higher dose of K. Increase in test weight of rice grains was recorded due to K application at higher doses that indicates it helped in proper grain filling in rice and utilization of other nutrients by crop as well. The results are in close agreement with the earlier findings Mali et.al 2016. They reported that, the yield was increased significantly with increasing levels of potassium along with recommended dose of N and P.

Table 1. Effect of potassium application on yield attributes of rice (*cv* Pusa Basmati-1)

Treatments	Tillers (No./m^2)			Filled grains (No./panicle)			Test weight (g)		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
K_0	191	222	207	207	109	158	21.01	21.90	21.46
K_{40}	196	224	210	217	126	172	21.58	22.18	21.88
K_{80}	199	226	212	233	151	192	22.05	22.64	22.35
K_{FP}	190	203	197	206	107	157	21.14	21.96	21.55
CD (0.05)	3.41	17.2	-	11.5	12.7	-	0.32	0.46	-

NS, non-significant at 0.05

Table 2. Effect of potassium application on rice yield (*cv* Pusa Basmati-1)

Treatments	Yield (kg ha^{-1})			Stover (kg ha^{-1})			Harvest index (%)		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
K_0	5473	4181	4827	6142	5900	6021	46.8	41.41	44.11
K_{40}	5690	4310	5000	6327	6692	6510	47.28	39.14	43.21
K_{80}	5784	5213	5499	6374	6709	6542	47.72	43.77	45.75
K_{FP}	5072	4020	4546	5908	4262	5085	46.58	48.85	47.72
CD (0.05)	151.6	421.4	-	213.9	574.7	-	NS	0.028	-

NS, non-significant at 0.05

CONCLUSION

The study inferred that application of K increased the yield and yield attributes of rice (cv Pusa Basmati-1) grown in Vertisols. The increase in effective grains as well as test weight indicated that K is essential for proper grain filling and also to attain optimum grain size. Thus, in order to ensure the sustainability and food security balanced application of potassium along with nitrogen and phosphorus is essential.

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Natural Resources Management to Improve Soil Health and Increased Crop Productivity

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ABSTRACT

The value added compost was prepared from low grade rock phosphate and various crop residues to assess the impact on soil health and crop productivity at Akola. Various crop residues (wheat straw and shredded cotton stalk) along with indigenous low grade rock phosphate (as a source of P) and urea (as a source of N) were used to prepare value added compost. The compost was prepared by pit method with intermittent turning at regular intervals. The changes in physical, chemical and biological properties were monitored during decomposition of crop residues up to 120 days. The colour of compost was rated as brown to greyish brown (Hue-10YR, Value-5 and Chroma-3 and 2) as per Munsell colour chart. The compost prepared from various crop residues along with various levels of rock phosphate have organic carbon in the range of 25.41 -28.25%, total N (1.17 - 1.34), C: N ratio (19.91-23.02), total P (1.48-1.94%) and total K (0.58-0.78%). The DTPA extractable micronutrient content was higher in compost prepared from wheat straw along with rock phosphate @ 12%. The microbial count was improved in compost prepared from wheat straw along with rock phosphate @12%. The compost prepared from wheat straw along with rock phosphate @ 12% was among the best in terms of various physical, chemical and biological parameters. Hence, the impact of value added compost prepared from wheat straw along with rock phosphate @ 12% on soil health and productivity of soybean and cotton-soybean rotation was assessed by combining various fertilizer treatments along with value added compost. The application of 100 % RDF (23.78 q ha^{-1}) and 50% RD + 50 % P through value added compost (22.51 q ha^{-1}) found at par and equally beneficial in producing higher grain yield of soybean when compared with 100 % RDF + FYM @ 5 t ha^{-1}. The application of chemical fertilizers along with value added compost and organics alone (100 % RD through FYM + remaining P through value added compost) helps in overall improvement of soil physical, chemical and biological condition. The soil quality index (SQI) was increased with the application of 50% RD + 50 % P through PC (3.47). In soybean-cotton rotation, application of 100 % recommended N of cotton and soybean through FYM (11 t ha^{-1} to cotton and 5 t ha^{-1} to soybean) and remaining dose of P and K through phosphocompost to cotton (80 kg ha^{-1}) and soybean (3.8 t ha^{-1}) was found to increase significantly the grain yield of soybean as well as seed and stalk yield of cotton. The higher SQI was obtained with the application of 100 % N through FYM + P compensation through phosphocompost.

The declined availability of FYM is being experienced in semi arid areas like Vidarbha consequent upon tendency of limiting farm animals due to increasing farm mechanization. Moreover, the commonly adopted practice of burning wheat residue has led to the decline in soil organic matter, pollution of the environment and lowering biological activity. The promotion of turning wheat residues into phosphocompost during the time lag of about two and half months between the harvest of wheat and planting kharif soybean and its utilization as alternate to FYM is a feasible option. The enriched organic manure prepared by using indigenous rock phosphate is a potential alternative to FYM which can be used as a component of INM.

Phosphorus is an element that is widely distributed in nature and occurs together with nitrogen and potassium, as a primary constituent of life. Under continuous cultivation, P inputs must be added to either maintain the soil P status of fertile soils or increase that of soil with inherent lower P fertility. Superphosphates are commonly recommended for correcting P deficiencies. However, India imports these fertilizers, which are often in limited supply and represent a major outlay resource-poor farmer. In addition, intensification of agricultural production in these regions necessitates the addition of P input not only to increase crop production but also to improve soil P status in order to avoid further soil degradation. India has reserve of 14.7 million tonnes of high grade rock phosphate (30

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per cent P_2O_5) and about 190 million tonnes of low grade rock phosphate with an average of 12 per cent P_2O_5 (Jaggi, 2000). The use of rock phosphate as a source of fertilizer P in acid soil is well known but it is not an effective phosphorus source for crop in neutral and alkaline soil.

More efforts in making use of low (non-premium) grade unreactive phosphate rock (PR) deposits are needed. Even under acid soil conditions, Indian phosphate rocks are not very effective because of their poor reactivity. Thus, to match the P needs of India, indigenous phosphate rocks need to be made more effective through modifications in the P release pattern of rock phosphate. Several techniques have been developed to modify low grade phosphate rocks to promote solubility of P in rock phosphate in different soils. But most of these techniques didn't reach the farmers' fields. Therefore, sincere and determined effort was made to implement the technologies of utilization by solubilizing phosphate rocks with organic residues to make phosphorus availability for crop plant in neutral and alkaline soil.

MATERIAL AND METHODS

A field experiment on soybean (2010-11 to 2014-15) and cotton –soybean rotation (2011-12-12 to 2016-17) was conducted to assess the impact value added compost on soil health and crop productivity in Inceptisols and Vertisols respectively at Research Farm, Dr. PDKV, Akola. A value added compost was prepared with wheat straw + rock phosphate 6, 9 and 12 % and shredded cotton stalk + rock phosphate 6, 9 and 12 % by pit method. The flow chart for preparation of value added compost is given below (Fig. 1).

1. Preparation of value added compost

The changes in physical, chemical and biological properties were monitored during decomposition of crop residues up to 120 days. The prepared compost was

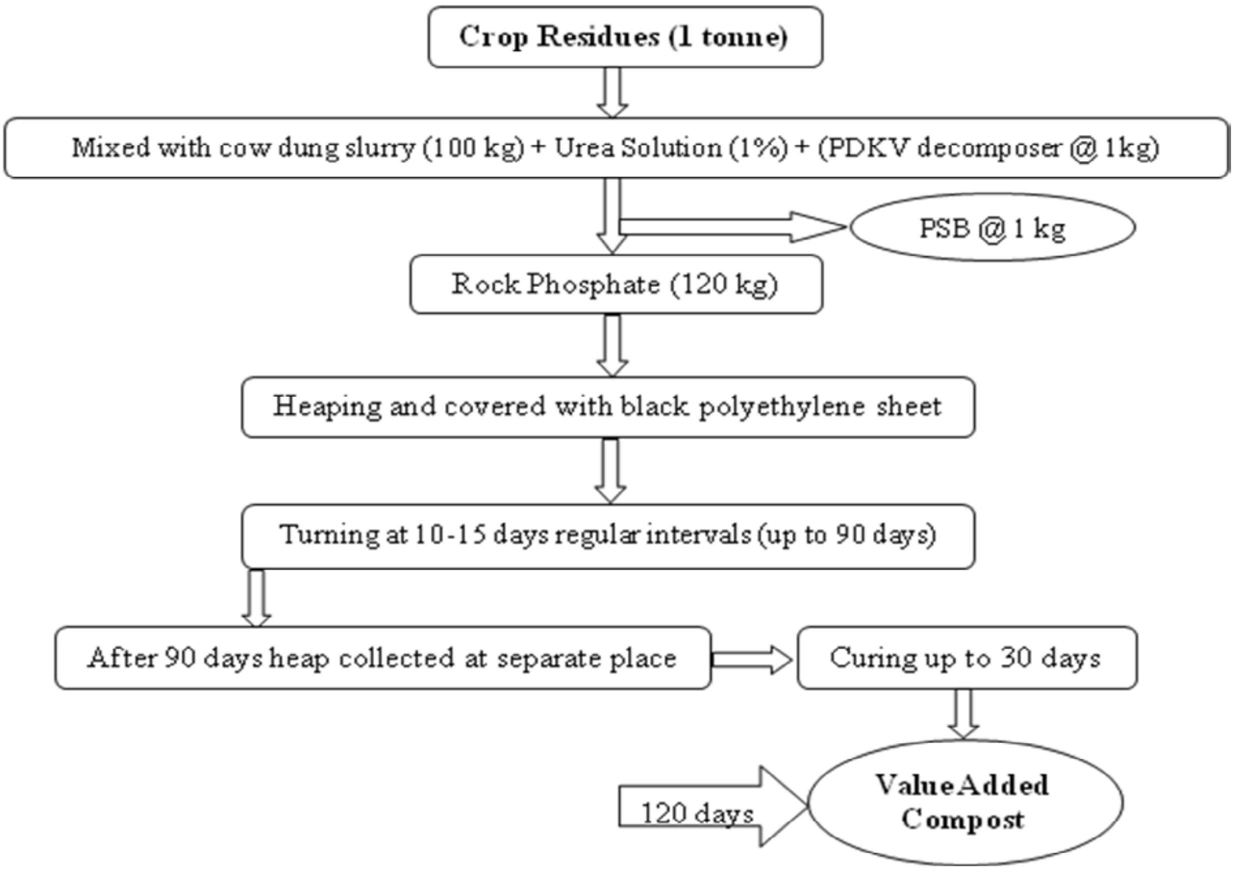

Fig. 1 Flow Chart for preparation of value added compost

Table 1: Chemical composition of value added compost

Particulars	Composition	Particulars	Composition
pH	7.44	Bulk Density, g kg^{-1}	0.713
EC (dS m^{-1})	0.76	Colour	Brown
Organic Carbon (%)	25.41	DTPA-Micronutrients (mg kg^{-1})	
Total N (%)	1.23	DTPA-Zn (mg kg^{-1})	2.35
C:N ratio	20.45	DTPA-Fe (mg kg^{-1})	7.17
Total P (%)	1.94	DTPA-Mn (mg kg^{-1})	3.68
Citrate Soluble P (%)	0.92	DTPA-Cu (mg kg^{-1})	0.34
Citrate Soluble P (%)	0.069	Boron (mg kg^{-1})	0.58
Total Potassium (%)	0.78	Microbial Count, CFU g^{-1} Soil	
Total S (%)	0.24	Bacteria (x 10^7)	39
NH_4-N (mg kg^{-1})	948	Fungi (x 10^7)	25
NO_3-N (mg kg^{-1})	768	Actinomycetes (x 10^7)	28

analyzed for various chemical parameters. Chemical composition of value added compost is given in Table 1. In order to assess the impact of value added compost a field experiment were conducted on soybean and cotton –soybean rotation for five years in Inceptisol and Vertisol, respectively.

2. Experiment on Soybean

The experiment was laid in Randomized Block Design (RBD) with eight treatments replicated three times. The treatments were absolute control, 100% RDF, 100% RDF + FYM @ 5 t ha^{-1}, 50% RDF + 50% P through phosphocompost, 75% RDF of N & P_2O_5 + 25% N through cotton stalk and 100% RDF through FYM and remaining P added through phosphocompost.

3. Experiment on Cotton –Soybean rotation

The experiment was laid in Randomized Block Design (RBD) with nine treatments replicated three times. The experiment was conducted to study the impact of phosphocompost in comparison with various resource conservation technologies on soybean –cotton rotation in Vertisol. The details of treatment imposed are given below (Table 2). Data generated were subjected to statistical analysis in RBD as per Panse and Sukhatme (1971).

Table 2: Treatment details under cotton –soybean rotation

Tr.	Treatment details	
	Cotton	Soybean
T_1	RDF	RDF
T_2	Dhaincha loppings 25 % N + Compensation of RDF	RDF
T_3	Cotton Stalk 25 % N composted with *Trichoderma viride* + Compensation of RDF	RDF
T_4	Wheat straw 25 % N + Compensation of RDF	RDF
T_5	Bio mulch (Farm waste) 25 % N + Compensation of RDF	RDF
T_6	Conc. Organics (Neemcake) 25 % N + Compensation of RDF	RDF
T_7	100 % N through FYM + Compensation of P through phosphocompost	RDF through FYM+ compensation of P through phosphocompost
T_8	50 % N through FYM + compensation of P through phosphocompost	RDF through FYM+ compensation of P through phosphocompost
T_9	Leucaena loppings 50% N + compensation of P from phosphocompost	RDF through FYM+ compensation of P through phosphocompost

Surface soil samples were collected at harvest of each crops and analyzed for various physical and chemical properties following standard methods. The soil samples were collected at critical growth stages for biological properties.

Results and Discussion

Productivity of soybean

The grain yield of soybean are presented in Table 3. The application of 100% NPK + FYM recorded significantly highest grain and stover yield during 2010-11 to 2014-15. The mean yield of soybean was higher in the NPK+ FYM @ 5 t ha^{-1} (26.14 q ha^{-1}) followed by 100% NPK (23.78 q ha^{-1}) and 50% RD + 50 % P through phosphocompost (22.51 g ha^{-1}). However, treatments viz; 100 % RD and 50 % RD + 50 % P through PC were found at par and equally beneficial in producing higher grain and stover yield.

Productivity of Cotton in Cotton –Soybean rotation

Seed cotton and stalk yield

The data in respect of seed cotton yield as influenced by various resource conservation treatments was found significant (Table 4). The pooled results revealed that significantly highest seed cotton yield (13.27 q ha^{-1}) was recorded with 25 % N through neem cake + compensation of RDF followed by 100 % RDF through chemical fertilizers (13. 18 q ha^{-1}), 25 % N through dhaincha loppings + compensation of RDF (12.50 q ha^{-1}) and 100 % N through FYM + Compensation of P through phosphocompost (12.33 q ha^{-1}) which were found to be at par with each other. The lower seed cotton yield was observed with the application of 50 % N through Leucaena loppings + compensation of P from phosphocompost.

Productivity of Soybean in Cotton –Soybean rotation

The data in respect of yield of soybean as influenced by various resource conservation treatments was found significant (Table 5). The pooled results revealed that significantly highest grain yield of soybean (22.46 q ha^{-1}) was observed with the application of 100 % N through FYM + remaining P & K through phosphocompost followed by 25 % N through dhaincha lopping, composted cotton stalk + compensation of RDF through chemical fertilizers and 100 % RDF through chemical fertilizers which were found to be on par with each other.

Table 3: Effect of different treatments on grain yield of soybean

Tr	Soybean	Grain Yield (q ha^{-1})					
		2010-11	2011-12	2012-13	2013-14	2014-15	Mean
T1	Control	14.91	17.75	17.67	16.75	12.06	15.83
T2	100 % RD	28.99	24.90	24.68	24.75	15.59	23.78
T3	100 % RD + FYM @ 5 t ha^{-1}	29.57	27.08	27.42	28.27	18.37	26.14
T4	50% RD + 50 % P through PC	20.85	24.33	23.93	25.72	17.74	22.51
T5	75% RD+ 25 % N through CS	21.89	21.18	21.33	21.92	15.12	20.29
T6	100 % RD through FYM + remaining P through PC	18.67	19.65	20.45	25.20	15.62	19.92
	SE (m±)	0.25	0.54	0.81	1.02	0.68	0.66
	CD at 5%	0.72	1.41	2.37	2.98	1.99	1.89

Table 4: Seed cotton yield (q ha^{-1}) as influenced by various treatments

Tr.	Treatment details Cotton	Soybean	Seed cotton 2011-12	2013-14	2015-16	Pooled Mean
T_1	RDF	RDF	12.69	18.04	8.81	13.18
T_2	25 % N (Dhaincha loppings) + Compensation of RDF	RDF	11.44	16.27	9.79	12.50
T_3	25 % N (composted Cotton Stalk) + Compensation of RDF	RDF	10.75	15.85	8.22	11.61
T_4	25 % N(Wheat straw) + Compensation of RDF	RDF	9.17	15.88	9.73	11.59
T_5	25 % N (Sorghum stubbles) + Compensation of RDF	RDF	9.94	15.25	8.40	11.19
T_6	25 % N (Neemcake) + Compensation of RDF	RDF	12.49	17.53	9.80	13.27
T_7	100 % N (FYM) + Compensation of P through phosphocompost (PC)	RDF through FYM+ compensation of P through phosphocompost (PC)	11.21	16.17	9.62	12.33
T_8	50 % N (FYM) + compensation of P through phosphocompost	RDF through FYM + compensation of P through PC	10.68	15.03	9.47	11.73
T_9	50% N (Leucaena loppings) + compensation of P from PC	RDF through FYM+ compensation of P through PC	10.42	14.12	8.45	11.00
	SE (m)±		0.66	0.57	0.37	0.39
	CD at 5 %		1.97	1.70	1.10	1.15

Soil Properties after harvest of soybean

Physical Properties

The bulk density in different treatments varied from 1.41 to 1.45 Mg m^{-3} (Fig. 2). The lowest bulk density (1.41 Mg m^{-3}) has been recorded with the application of 100 % RD through FYM + remaining P through PC. The reduction in bulk density may be attributed to better aggregation, increase in organic matter under the treatments of integrated use of chemical fertilizers and organic manures.

The hydraulic conductivity of soil varied from 0.73 to 0.87 cm h^{-1}. The hydraulic conductivity showed considerable improvement under treatments of INM and organics as compared to only chemical fertilizers. The highest hydraulic conductivity was recorded with the application of 100 % RD through FYM + remaining P through PC (0.87 cm h-1) followed by 100 % RD + FYM @ 5 t ha^{-1} (0.79 cm h^{-1}) and 50% RD + 50 % P through PC (0.81 cm h^{-1}). The treatments devoid of organic manures and crop residues resulted into lesser accumulation of organic matter in the soil, leading to comparatively poor soil physical condition.

The aggregate stability of the soil was evaluated in terms of mean weight diameter (MWD) of the aggregate particles. The mean weight diameter was significantly highest (0.96 mm) under 100% RD through organics which was superior to all the remaining treatments. The increase in hydraulic conductivity is associated with decrease in bulk density and increase in pore space as a result of increase in MWD (Singh, 2010).

Table 5: Grain yield of soybean as influenced by various treatments

Tr	Treatment details		Grain yield of soybean			
	Cotton	Soybean	2012-13	2014-15	2016-17	Pooled Mean
T_1	RDF	RDF	28.15	11.38	26.55	22.02
T_2	25 % N (Dhaincha loppings) + Compensation of RDF	RDF	27.97	12.50	25.64	22.03
T_3	25 % N (composted Cotton Stalk) + Compensation of RDF	RDF	28.11	10.65	26.27	21.68
T_4	25 % N(Wheat straw) + Compensation of RDF	RDF	28.79	9.78	23.55	20.71
T_5	25 % N (Sorghum stubbles) +Compensation of RDF	RDF	23.04	9.42	26.19	19.55
T_6	25 % N (Neemcake) + Compensation of RDF	RDF	22.46	10.90	27.20	20.19
T_7	100 % N (FYM) + Compensation of P through phosphocompost	RDF (FYM) + P compensation from PC	28.45	12.05	26.88	22.46
T_8	50 % N (FYM) + compensation of P through phosphocompost	RDF (FYM) + P compensation from PC	28.51	10.42	22.34	20.42
T_9	50% N (Leucaena loppings) + compensation of P from PC	RDF (FYM) + P compensation from PC	21.91	11.55	23.85	19.10
	SE (m)±		0.52	0.60	0.95	0.53
	CD at 5 %		2.71	1.72	2.84	1.58

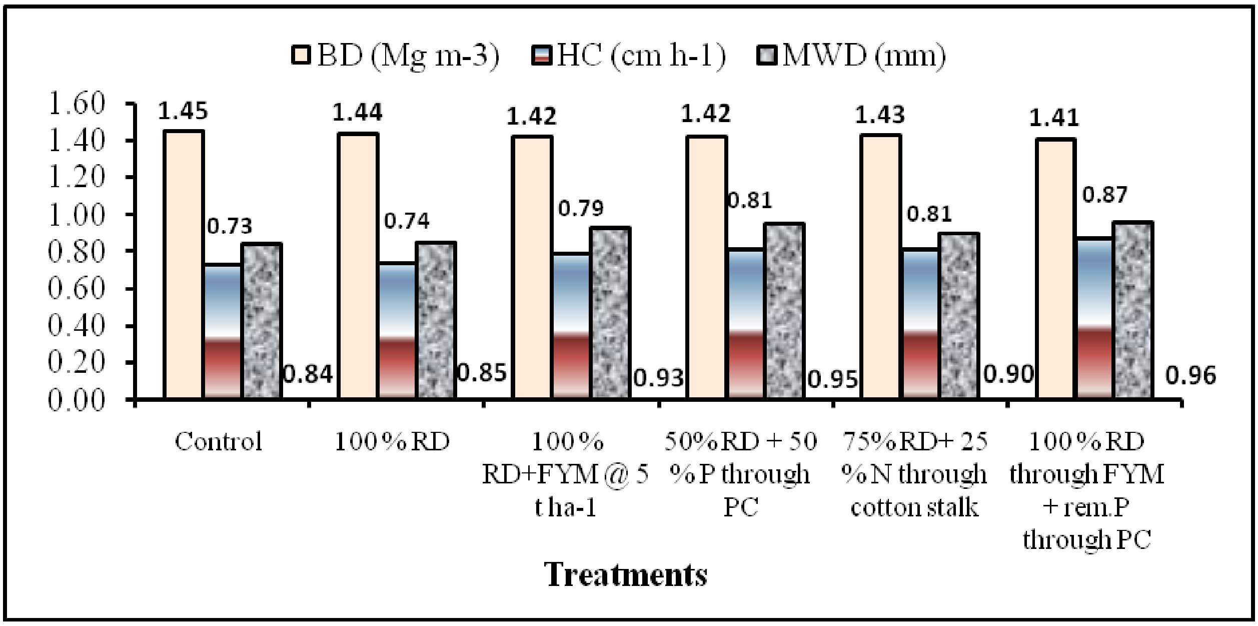

Fig. 2 Soil physical properties as influence by various nutrient management practices

Chemical Properties

The soil chemical properties and nutrient status after harvest of soybean are presented in Table 6. The organic carbon content was significantly increased with the application 100% RD + FYM @ 5 t ha^{-1} (6.68 g kg^{-1}) followed by 100 % RD through FYM + remaining P through(6.48 g kg^{-1}) and 50 % RD + 50 % P through PC (6.42 g kg^{-1}). The available nitrogen status after harvest of soybean was significantly increased with the application of 100 % NPK + FYM @ 5 t ha^{-1} (247 kg N ha^{-1})followed by 50 % RD + 50 % P through PC (228 kg N ha^{-1}). The initial status of available N was 158 kg ha^{-1}. Substantial increase in available N was noted under INM treatments. This is due to added root and above ground biomass through soybean as a result of better crop growth under these treatments. The application of 50 % RD + 50 % P through PC (15.96 kg ha^{-1}) and 100% NPK (15.92 kg ha^{-1}) also found equally beneficial in maintaining phosphorus regime of soil indicating possibility of compensating 50% RD of P through phosphocompost. The application of 100 % NPK + FYM @ 5 t ha^{-1} (422 kg ha^{-1}) significantly increased the available K status of soil followed by 50 % RD + 50 % P through PC (390 kg ha^{-1}) and 100% NPK (390 kg ha^{-1}). The improvement in soil fertility status as influenced by combined use of organic and inorganic fertilizers were also reported by Singh *et al.* (1980).

Biological Properties (Active Pools of Organic Carbon)

The Soil Microbial Biomass Carbon (SMBC) was significantly increased under integrated nutrient management in comparison with only chemical fertilizers

Table 6: Effect of various treatments on soil chemical properties after harvest soybean (2014-15)

Treatment Details	Org. Carbon (g kg^{-1})	Av. N (kg ha^{-1})	Av. P (kg ha^{-1})	Av. K (kg ha^{-1})
Control	4.74	159	9.71	310
100 % RD	6.09	224	15.92	390
100 % RD + FYM @ 5 t ha^{-1}	6.68	247	17.49	422
50% RD + 50 % P through PC	6.42	228	15.96	390
75% RD+ 25 % N through cotton stalk	6.30	203	13.34	386
100 % RD through FYM + remaining P through PC	6.48	208	13.04	370
CD @ 5%	0.87	11.25	4.59	26.32
Initial Value	4.80	158	9.50	320

Table 7: Effect of various treatments on soil biological properties at grant growth stages of soybean in Inceptisol

Treatment Details	SMBC (µg g^{-1} soil)	DHA (µg TPF g^{-1} 24 h^{-1})	Al. Phosphatase (µg p-nitrophenol g^{-1} 24 h^{-1})	Urease activity (µg NH_4-N g^{-1} 24 h^{-1})	CO_2 (mg 100 g^{-1} soil)
Control	118.8	40.46	80.02	52.23	47.18
100 % RD	191.5	54.33	119.70	71.83	67.23
100 % RD + FYM @ 5 t ha^{-1}	216.8	55.43	134.80	80.54	80.69
50% RD + 50 % P through PC	175.3	51.17	114.73	71.97	68.29
75% RD+ 25 % N through cotton stalk	170.6	54.72	111.76	70.72	65.25
100 % RD through FYM + remaining P through PC	214.8	49.57	125.65	68.32	67.18
SE (m±)	2.92	2.36	3.21	3.31	3.47
CD at 5%	7.67	6.20	8.43	8.70	9.13

(Table 7). The application 100% N through FYM and remaining P through phosphocompost recorded significant improvement in soil microbial biomass carbon over all other treatments of INM. It was also a soil restorative practice causing considerable improvement in soil health. These results are in conformity with Chakraborty *et al.* (2011). Higher dehydrogenase activity was noticed in conjunction with 100% NPK + FYM. Significant increase in dehydrogenase activity with the application of FYM might be due to increase in microbial growth with addition of carbon substrate. Alkaline phosphate showed significant improvement under 100% RD+ FYM 5 t ha^{-1}over chemical fertilizer. The highest urease activity was observed with the application of 100 % RD + FYM 5 t ha^{-1}. The significantly higher CO_2 evolution (80.69 mg 100 g^{-1}) was observed under 100% RD + FYM 5 t ha^{-1} followed by 50% RD + 50 % P through PC (68.29 mg 100 g^{-1}). Higher CO_2 evolution in FYM treated soil is indicative of the nutrient turn over at higher carbon expenses met through added organic carbon.

Passive Pools of organic carbon

The passive pools were assessed at 50% flowering stage of soybean (Table 8). The results indicated that, application of 100% RDF + FYM @ 5 t ha^{-1} significantly increased passive pools comprising fulvic (0.35%) and humic acid (0.28%). The application of 100% N through FYM and remaining P through phosphocompost were found promising over RDF through chemical fertilizers. Ghosh *et al.* 2010 and 2012, reported that one of the known and easy ways for carbon enrichment in soils is incorporation of crop residues or organic amendments.

All the biological properties (active pools of organic carbon) were positively and significantly correlated with passive pools of organic carbon (Table 9). The highest correlation was observed among soil microbial biomass carbon and humic acid fraction (r^2 = 0.864^{**}) followed by FA-C (r^2 = 0.849^{**}). There also exists a positive and significant correlation among SMB-C, WS-C and WS-CHO with humic and fulvic acid.

Table 8: Effect of various treatments on passive pools of organic carbon at 50 per cent flowering of soybean

Treatments		OM(g kg^{-1})	Passive pool (%)		FA-C: HA-C
			FA-C	HA-C	ratio
T1	Control	7.64	0.23	0.21	1.10
T2	100 % RDF	9.36	0.28	0.23	1.22
T3	100 % RDF + FYM 5 t ha^{-1}	9.77	0.35	0.28	1.25
T4	50 % RDF + 50% P through Phosphocompost	9.41	0.28	0.25	1.12
T5	75 % RDF +2 5% N through cotton stalk	8.68	0.29	0.26	1.12
T6	100% RDF through FYM + remaining P through Phosphocompost	9.65	0.33	0.28	1.18
	SE (m±)	0.76	0.0051	0.0048	-
	CD at 5 %	1.64	0.016	0.014	-

Table 9. Correlation between different organic carbon fractions and yield of soybean

Fractions	SMBC	SMBN	WSC	WS-CHO	Grain
OC	0.546**	0.672**	0.495**	0.435*	0.479**
HA	0.864**	0.749**	0.617**	0.622**	0.558**
FA	0.849**	0.737**	0.574**	0.679**	0.413*

*Significant at 5%   ** Significant at 1%

Soil Quality Index in soybean

The highest SQI (3.47) was observed under 50% RD + 50% P through phosphocompost followed by100 % RDF + FYM 5 t ha^{-1} (3.17) (Fig. 3). Among all the treatments, application of NPK fertilizers in combination with organics maintained significantly highest soil quality index.

Soil Quality Index under Cotton –soybean rotation

The data in respect of soil quality index (SQI) is presented in Fig 4. The highest SQI (2.37) was observed under 100% through FYM + compensation of phosphorus through phosphocompost followed by 50 % through FYM + P compensation from phosphocompost (2.30) which was on par with each other. The SQI obtained in 25 % N through dhainch lopping + RDF compensation (2.26) was statically on par with 50 % through FYM + P compensation from phosphocompost (2.30).

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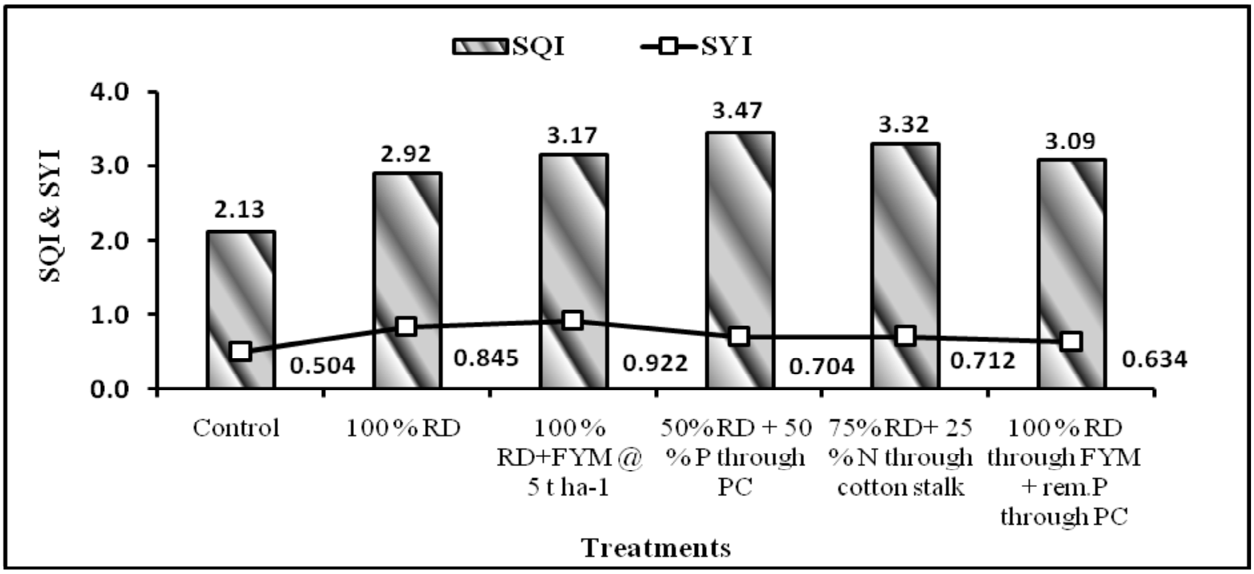

Fig. 3 SQI and SYI as influenced by nutrient management under soybean grown in Inceptisol

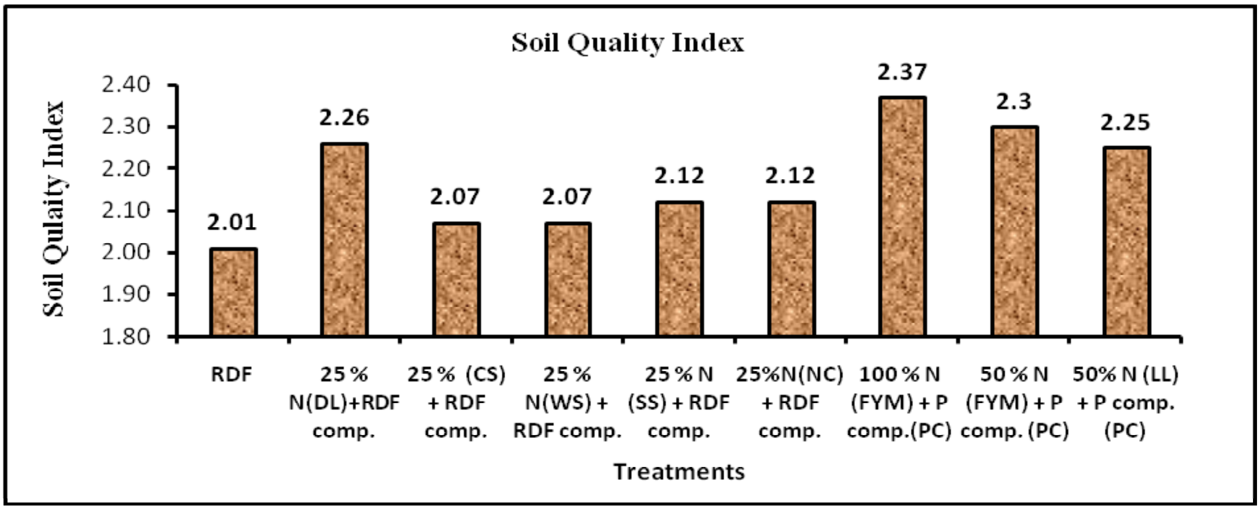

Fig. 4 Soil Quality Index under soybean and cotton in Cotton –soybean rotation

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Assessment of Molybdenum Status in Soils of Raigad District of Maharashtra

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ABSTRACT

The present study entitled "Assessment of molybdenum status in soils of Raigad district of Maharashtra" was conducted during 2016-17 at Department of Soil Science & Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra with objective to assess the molybdenum status in soils of Raigad district and to study the relationship of molybdenum with soil properties. Geo-referenced surface soil samples representing different tehsils were collected from Raigad district during 2015-16. pH of soils of Raigad district varied from 5.80 to 7.11 indicates acidic to neutral in reaction. Organic carbon lies in the range of 4.19 to 11.21 g kg^{-1} and electrical conductivity ranged from 0.08 to 0.49 dS m^{-1}. Calcium carbonate content found in the range of 1.00 to 3.87 percent. Available nitrogen content of the district varied from 100.06 to 298.87 kg ha^{-1}. Available molybdenum lies in the range of 0.01 to 0.64 mg kg^{-1}. The nutrient index for molybdenum is 1.87 for Raigad district. It is also noticed that 37.62 percent soil samples are deficient in available molybdenum. It can be observed that there is a positive correlation between pH and available molybdenum (r=+0.714**). Available soil molybdenum increase with increase in soil pH. Available molybdenum was found to have significant and negetive correlation with organic carbon content r= -0.815 and decrease with increase in organic carbon content.

Molybdenum is an important trace element found in the soil and is required for growth of most biological organisms including plants and animals. Molybdenum is an exception among micronutrients, in that, it is readily translocated in an ionic form and its deficiency symptoms are generally yellowing and stunting of the plant like N deficiency and inter venal mottling and cupping of the older leaves followed by leaves tips and margins. Root interception and mass flow are considered to be the important mechanisms controlling the movement of molybdenum to the plants roots. Without molybdenum plants cannot perform the biochemical process of making essential nitrogen compound. Molybdenum is involved in enzyme systems relating to nitrogen fixation by bacteria growing symbiotically with legumes.

Molybdenum is unusual among micronutrients and is becoming less available to plants at low pH. Availability of molybdenum for plants increases together with increasing soil pH. Available molybdenum shows significant positive correlation with soil pH (Adhikari and Patel, 2013). Molybdenum deficiency is usually associated with acid soils. (pH< 5.5), particularly those which are geologically old and highly leached soil. Soils with pH values more than 6.0 to 6.5 rarely require molybdenum

MATERIALS AND METHODS

Location : Raigad district lies between $17^0 51'$ and $19^0 80'$ N latitude and $72^0 50'$ and $73^0 40'$ E longitude with an altitude of 10 to 50 meters above mean sea level (MSL). Raigad district is surrounded by Sahayadri ranges (Western Ghat) in the east and the Arabian sea on the west and form natural boundaries.

Soil type : The soil of the Raigad district are essentially derived from the Deccan trap which is the predominant rock formation of the district. The main types of soil found in the district are black soil, khar or salt soil, coastal alluvium and literate soils. The predominant soil in the district is laterite which varies in colour from bright red to brownish red owing to the preponderance of hydrated iron oxides. They are always acidic and fairly well supplied with nitrogen and organic matter.

***Climate and Weather Condition*:** Climate of Raigad district is typical hot and humid that of the west coast of India characterized with plentiful and regular monsoon rainfall. The period from March to May is one of increasing temperatures The average minimum temperature is 17.7°C and maximum average temperature is 31.8°C. The average annual rainfall in the district is 2484.32 mm.

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***Collection of soil sample* :** Geo-referenced surface (0-20 cm) soil samples representing different soils were collected. The villages were selected randomly in the district, so the sampling sites scattered uniformly in each tehsils of the district. The geo-referenced soil samples were collected from all the tehsils of Raigad district of Maharashtra. One hundred nine geo-referenced soil samples were collected from the district

Methods adopted for analysis : Soil pH was determined with the help of pH meter in 1: 2.5 soil water suspension as described by (Jackson 1973). EC of the soil samples were determined in clear supernatant liquid obtained from 1:2.5 soil water suspension with the help of conductivity meter (Jackson 1973). Organic carbon of the samples were determined by Walkely and Black wet-oxidation method as given by Nelson and Sommers (1982). Calcium carbonate was determined by rapid titration method as given by Piper (1966). Available molybdenum was determined by Grigg's reagent method given by Grigg (1953). The data pertaining to available micronutrient were categorized as low, medium, high based on their limits. The nutrient indices were calculated by using formula given by Parkar *et.al* (1951). Correlation of available molybdenum with pH, organic carbon and calcium carbonate were determined as described by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Range of soil pH of Raigad district (Table 1) is from 5.80 to 7.11 indicating acidic to neutral reaction. Most

Table 1. Status of pH (1:2.5) of soils in Raigad district

S.N.	Name of Tehsil	No. of soil samples	Soil pH				
			Range	Mean	acidic	neutral	alkaline
1	Mahad- Poladpur	10	6.36-7.07	6.72	4 (40.00)	6 (60.00)	0 (0.00)
2	Mangaon	10	5.92-6.9	6.42	5 (50.00)	5 (50.00)	0 (0.00)
3	Roha	10	6.00-7.01	6.80	3 (30.00)	7 (70.00)	0 (0.00)
4	Mahasala-Sriwardhan	10	5.83-6.81	6.27	6 (60.00)	4 (40.00)	0 (0.00)
5	Tale	9	6.40-7.05	6.82	2 (22.22)	7 (77.77)	0 (0.00)
6	Pali	10	6.20-7.01	6.75	4 (20.00)	6 (80.00)	0 (0.00)
7	Murud	10	5.80-7.11	6.69	4 (40.00)	6 (60.00)	0 (0.00)
8	Alibagh	10	6.30-7.04	6.50	5 (20.00)	5 (80.00)	0 (0.00)
9	Pen-ghalapur	10	5.79-7.10	6.69	3 (30.00)	7 (70.00)	0 (0.00)
10	Panwel	10	6.30-7.01	6.69	4 (40.00)	6 (60.00)	0 (0.00)
11	Karjat	10	5.83-6.90	6.46	5 (50.00)	5 (50.00)	0 (0.00)
	District	109	5.80-7.11	6.65	45 (41.28)	64 (58.72)	0 (0.00)

(Figures in parenthesis indicate percentage)

Table 2. Status of electrical conductivity in soils of Raigad district

S.N.	Name of Tehsil	No. of soil samples	Electrical conductivity (dS m^{-1})				
			Range	Mean	low	medium	high
1	Mahad- Poladpur	10	0.10-0.23	0.14	10	0(0.00)	0(0.00)
2	Mangaon	10	0.15-0.68	0.25	10	0(0.00)	0(0.00)
3	Roha	10	0.11-0.31	0.17	10	0(0.00)	0(0.00)
4	Mahasala-Sriwardhan	10	0.11-0.32	0.21	10	0(0.00)	0(0.00)
5	Tale	9	0.08-0.34	0.21	9	0(0.00)	0(0.00)
6	Pali	10	0.10-0.47	0.23	10	0(0.00)	0(0.00)
7	Murud	10	0.14-0.49	0.22	10	0(0.00)	0(0.00)
8	Alibagh	10	0.19-0.38	0.23	10	0(0.00)	0(0.00)
9	Pen-ghalapur	10	0.14-0.53	0.32	10	0(0.00)	0(0.00)
10	Panwel	10	0.11-0.48	0.30	10	0(0.00)	0(0.00)
11	Karjat	10	0.11-0.38	0.32	10	0(0.00)	(0.00)
	District	109	0.08-0.49	0.23	109(100)	0(0.00)	0(0.00)

(Figures in parenthesis indicate percentage)

Table 3. Status of calcium carbonate of soil in Raigad district

S.N.	Name of Tehsil	No. of soil samples	$CaCO_3$ content (%)				
			Range	Mean	low	medium	high
1	Mahad- Poladpur	10	1.18-2.98	1.93	10(100.00)	0(0.00)	0(0.00)
2	Mangaon	10	1.17-3.87	2.04	9(90.00)	1(10.00)	0(0.00)
3	Roha	10	1.25-2.87	1.83	10(100.00)	0(0.00)	0(0.00)
4	Mahasala-Sriwardhan	10	1.00-2.86	1.77	10(100.00)	0(0.00)	0(0.00)
5	Tale	9	1.24-2.87	1.89	9(100.00)	0(0.00)	0(0.00)
6	Pali	10	1.31-2.98	2.21	10(100.00)	0(0.00)	0(0.00)
7	Murud	10	1.50-3.04	2.20	9(90.00)	1(10.00)	0(0.00)
8	Alibagh	10	1.93-2.56	2.22	10(100.00)	0(0.00)	0(0.00)
9	Pen-ghalapur	10	2.18-2.85	2.58	10(100.00)	0(0.00)	0(0.00)
10	Panwel	10	1.50-2.50	2.20	10(100.00)	0(0.00)	0(0.00)
11	Karjat	10	1.05-2.96	2.10	10(100.00)	0(0.00)	0(0.00)
	District	109	1.00-3.87	2.08	107(98.16)	2(1.84)	0(0.00)

(Figures in parenthesis indicate the percentage)

of the soils were acidic to neutral in Konkan region of Maharashtra, Gajanan *et al*. (1978). pH of the soils in Konkan and North Maharashtra ranged from 5.30 to 8.2 (Patil and Ahire 2013). Electrical conductivity of the soils of Raigad district (Table 2) ranges from 0.08 to 0.49 dS m^{-1} with mean of 0.23 dS m^{-1}. Calcium carbonate content (Table 3) ranged from 1.00 to 3.87 per cent with mean value of 2.08 percent of the district. Organic carbon content (Table 4) was in the range of 4.19 to 11.21 g kg^{-1} with mean value of 7.17 g kg^{-1}. Organic carbon in North Maharashtra and Konkan region varied from 3.7 to 9.7 g kg^{-1} (Patil and Ahire 2013). Available nitrogen (Table 5) was found to be varied from 100.06 to 298.87 kg ha^{-1} with mean value of 183.43 kg ha^{-1} in Palghar district. The available molybdenum (Table 6) ranges from 0.01 to 0.64 with mean of 0.30 mg Kg^{-1}. Available molybdenum in acid soil of

Table 4. Status of organic carbon content of soils in Raigad district

S.N.	Name of Tehsil	No. of soil samples	Organic carbon content (g kg^{-1})				
			Range	Mean	Low	Medium	High
1	Mahad-Poldpur	10	4.40-9.78	7.35	1 (10.00)	4 (40.00)	5 (60.00)
2	Mangaon	10	4.50-9.85	8.37	1 (10.00)	3 (30.00)	6 (60.00)
3	Roha	10	4.25-9.35	5.88	5 (50.00)	3 (30.0)	2 (20.00)
4	Mahasala-Sriwardhan	10	4.69-10.96	8.83	1 (10.00)	3 (30.00)	6 (60.00)
5	Tale	9	4.5-9.9.84	7.26	2 (22.22)	2 (22.22)	5 (55.56)
6	Pali	10	4.61-9.74	6.46	2 (20.00)	5 (50.00)	3 (30.00)
7	Murud	10	4.19-11.01	6.73	4 (40.00)	3 (30.00)	3 (30.00)
8	Alibagh	10	4.62-9.85	6.07	3 (30.00)	5 (50.000	2 (30.00)
9	Pen-ghalapur	10	4.85-10.36	6.92	1 (10.00)	6 (60.00)	3 (30.00)
10	Panwel	10	4.45-10.96	7.25	4 (40.00)	2 (20.000)	4 (40.00)
11	Karjat	10	4.48-11.21	7.84	1 (10.00)	3 (30.00)	6 (60.00)
	District	109	4.19-11.21	7.17	25 (22.93)	39 (35.77)	45 (41.28)

Table 5. Status of available nitrogen content in soils of Raigad district

S.N.	Name of Tehsil	No. of soil samples	Available nitrogen (kg ha^{-1})					Nutrient indices
			Range	Mean	low	medium	high	
1	Mahad- Poladpur	10	114.89-269.85	101.63	10(100.00)	0(0.00)	0(0.00)	1.00
2	Mangaon	10	112.8-296.36	220.74	10(100.00)	0(0.00)	0(0.00)	1.00
3	Roha	10	100.33-295.36	181.36	9(90.00)	1(10.00)	0(0.00)	1.10
4	Mahasala-Sriwardhan	10	115.56-294.85	196.38	8(80.00)	2(20.00)	0(0.00)	1.20
5	Tale	9	158.56-298.69	232.87	7(77.77)	2(22.23)	0(0.00)	1.22
6	Pali	10	102.96-298.87	185.80	8(80.00)	2(20.00)	0(0.00)	1.20
7	Murud	10	112.89-278.99	181.43	10(100.00)	0(0.00)	0(0.00)	1.00
8	Alibagh	10	90.01-265.88	168.31	9(90.00)	1(10.00)	0(0.00)	1.10
9	Pen-ghalapur	10	100.06-266.56	177.04	10(100.00)	1(10.00)	0(0.00)	1.20
10	Panwel	10	102.36-228.96	162.88	9(90.00)	1(10.00)	0(0.00)	1.10
11	Karjat	10	127.83-290.36	209.36	8(80.000	2(20..0)	0(0.00)	1.20
	District	109	100.06-298.87	183.43	97(88.99)	12(11.01)	0(0.00)	1.11

(Figures in parenthesis indicate percentage)

Srivardhan area of Kolaba and Karjat varied from 0.05 to 0.20 and 0.15 to 0.45 mg Kg^{-1}, respectively (Chavan *et al.* 1980). The data revealed that mean availability of Mo in Raigad district was found highest in Roha and Alibagh tehsil (0.41 mg Kg^{-1}) and lowest in Mahasala- Sriwardhan (0.1 mg Kg^{-1}) tehsil. In Raigad 37.62 percent soils are in low in available molybdenum, 34.87 percent contain medium and 26.61 percent samples contain high available molybdenum content. All the tehsils of Raigad also showed deficiency of molybdenum in soil, the highest percent of deficiency was found in Mahasala – Srivardhan tehsil (77.77%) followed by Mangaon (60.00%) tehsil.

Relationship of available Molybdenum with soil properties

Positive correlation is observed between pH and available molybdenum (r=+0.714**) as shown in Table 7. Available molybdenum had highly significantly correlated with pH.(Gupta and Dabas, 1980). Available soil molybdenum increase with soil pH. Available molybdenum

Table 6.Status of available molybdenum in soils of Raigad district

S.N.	Name of Tehsil	No. of soil samples	Available molybdenum (mg Kg^{-1})					Nutrient indices
			Range	Mean	Low	Medium	High	
1	Mahad-Poldpur	10	0.09-0.62	0.30	4 (40.00)	2 (20.00)	4 (40.00)	2.00
2	Mangaon	10	0.02-0.41	0.16	6 (60.00)	4 (40.00)	0 (0.00)	1.40
3	Roha	10	0.10-0.64	0.41	2 (20.00)	3 (30.00)	5 (50.00)	2.30
4	Mahasala-Sriwardhan	10	0.01-0.34	0.10	7 (77.77)	2 (22.22)	0 (0.00)	1.22
5	Tale	9	0.09-0.54	0.32	3 (30.00)	4 (40.00)	3 (30.00)	2.00
6	Pali	10	0.09-0.57	0.37	2 (20.00)	5 (50.00)	3 (30.00)	2.10
7	Murud	10	0.01-0.64	0.37	4 (40.00)	2 (20.00)	4 (40.00)	2.00
8	Alibagh	10	0.07-0.57	0.41	2 (20.00)	3 (30.00)	5 (50.00)	2.30
9	Pen-ghalapur	10	0.02-0.50	0.30	3 (30.00)	6 (60.00)	1 (10.00)	3.00
10	Panwel	10	0.06-0.61	0.34	4 (40.00)	2 (20.00)	4 (40.00)	2.10
11	Karjat	10	0.01-0.42	0.20	5 (50.00)	5 (50.00)	0 (0.00)	1.50
	Raigad district	109	0.01-0.64	0.30	41 (37.62)	38 (34.87)	29 (26.61)	1.87

(Figures in parenthesis indicate the percentage)

content below the critical level was found in acid oils with pH less than 6.5. In acid soils, much of the molybdenum may be associated with sesquioxides, especially the iron oxides. In highly leached acid soils of Mo combines very strongly with sesquioxides and clay minerals. Concentration of MoO_4^{2-} increases 100-fold for each unit increase in pH (Lindsay *et al.* 1972). The available molybdenum was found to have significant and negative correlation with organic carbon content (r= -0.815**) as depicted in Table 7. Available soil molybdenum decrease with increase in organic carbon content. Available molybdenum showed significant and negative correlation with organic carbon (r=- -0.341**) (**Rawat and Mathpal, 1981**).

Table 7. Karl Pearson's correlation of available molybdenum with soil properties

S.N.	Parameters	Molybdenum
1	pH	(r=+0.714**).
2	EC	0.101^{NS}
3	Ca CO_3	NS
4	Organic carbon	(r= - 0.815**).
5	Available nitrogen	NS

* significant at 5 % level * significant at 1% level

CONCLUSION

From the present investigation, it is concluded that, soils of Raigad district were found acidic to neutral in pH, low EC, low to high in organic carbon, low in calcium carbonate and low in nitrogen. . The available molybdenum in Raigad district ranges from 0.01 to 0.66 with mean of 0.30 mg Kg^{-1}. In Palghar district 37.60 percent soils are low in available molybdenum content. All the tehsils of the Raigad district showed deficiency of molybdenum in soil. The highest deficiency was found in Mahasala-Sriwardhan (77.77%) tehsil.

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Effect of Foliar Application of Gibbrellic Acid on Pigeonpea [*Cajanus cajan* (L.)] under Rainfed Conditions

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ABSTRACT

A field experiment was conducted at the Agriculture Research Station (Dr. PDKV), Buldana during 2016 and 2017, to study the effect of foliar application of gibbrellic acid on pigeonpea [*Cajanus cajan* (L.)] under rainfed conditions. In pigeonpea, ten treatments comprising gibbrellic acid–management practices (application of 25, 50, 75 ppm GA_3 at flowering, pod development stages and control) were tested. Results indicated that two applications of 50 and 75 ppm GA_3 at flowering and pod development stages recorded significantly higher number of branches per plant, number of pods per plant, seed index and grain yield than no application of the GA_3. The effect of the various GA_3 management treatments on the protein content (%) was found non significant during 2016 and 2017. Two applications of 50 and 75 ppm GA_3 at flowering, pod development stages recorded higher rain water use efficiency and higher gross monetary returns.

India is the largest producer of pulses in the world with 24% share in the global production. The major pulse crops of the country are chickpea (48%), pigeonpea (15%), mungbean (7%), urdbean (7%), lentil (5%) and field pea (5%) (IIPR, 2011). In the country, the major pulse-growing states are Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Karnataka and Andhra Pradesh, which together account for about 80% of the total production (Ali and Gupta, 2012). Despite the increase in the production, average pulse yields in India are much lower than the world average. The requirement of pulses has been projected to reach 32 million tonnes by 2050 taking into account with the estimated growth of the population to 1.69 billion by 2050.

Pigeonpea which is also known as red gram or arhar, is second most important crop of the country after chickpea. It is mainly used as split dal for making sour or curry. Pigeonpea is a major and cheap source of protein compared to animal protein. It accounts for about 15% of total pulses produced in the country. Similar to the case of other pulses, India is the major pigeonpea producing country, contributing almost 80% of the total production and area in the world (Annonymous, 2018).

A number of biotic and abiotic factors limit realization of the true potential of pigeonpea. The economic loss in pigeonpea production from abiotic constraints is higher than that from biotic constraints. Frequent droughts are a major abiotic constraint to enhancing productivity and production. Frequent droughts in the low-rainfall, semi-arid areas cause considerable loss in pigeonpea production. In the semi-arid tropics, pigeonpea is often grown as an intercrop in the rainy season and its reproductive growth occurs on residual moisture left after the harvest of a companion crop. Lack of moisture during the reproductive phase, especially in regions where farmers grow medium-to-long duration varieties, often leads to a situation of terminal drought, affecting crop yield substantially (Parthasarathy, *et al.*, 2010).

In pigeonpea vegetative and reproductive stage, occurs side by side and hence always there is competition for available assimilates between vegetative and reproductive sinks. On the other hand, always there is a limitation of source particularly at flowering and pod development stages. Apart from its genetic makeup, the major physiological constraints limiting pigeonpea's yield are flower and fruit drop (Ojeaga and Ojehomon, 1972). There is possibility to overcome these constraints by agronomic interventions such as the use of plant growth regulators. Plant hormones are group of structurally

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unrelated compounds which plays diverse and vital role in plant growth and development. Almost all the developmental stages of plant are controlled by plant hormones. Plant growth regulators are known to improve physiological efficiency including photosynthetic ability of plant and offer significant role in realizing higher crop yields. The plant growth regulators are also known to enhance the source sink relationship and stimulate the translocation of photo assimilates and thereby increase the productivity.

Gibberellic acid (GA_3), a plant hormone stimulating plant growth and development, is a tetracyclic di-terpenoid com-pound. Gibbrellic Acids stimulates seed germination, trigger transitions from meristem to shoot growth, juvenile to adult leaf stage, vegetative to flowering, determines sex expression and grain development along with an interaction of different environ-mental factors viz., light, temperature and water (Gupta and Chakrabarty, 2013).

With this background in view, the present investigation was planned to assess the effect of Gibbrellic Acid (GA_3) on growth, yield and economics of pigeonpea production.

MATERIAL AND METHODS

The present experiment was conducted at the Agriculture Research Station (Dr. PDKV), Buldana, Maharashtra, India during 2016 and 2017. The soil of experimental plot was clayey and slightly alkaline (pH 8.0), with available nitrogen (232 kg ha^{-1}), phosphorus (21 kg ha^{-1}) and potassium (358 kg ha^{-1}) content. Geographically Buldana is situated between $20^0$32'07.27N $76^0$11'24.43E and its mean height above sea level is 654 m. It receives most of the rainfall from South-West monsoon, commencing from middle of June. The normal monsoon season precipitation approximates to about 720 mm receives in about 40 to 45 rainy days from the middle of June to September. The pigeonpea crop received a rainfall of 690mm and 1009 mm during 2016 and 2017, respectively. For studying the effect of foliar application of gibbrellic acid on pigeonpea [*Cajanus cajan* (L.)] under rainfed conditions, randomized block design was used. The details of the treatments and symbols used are given in Table 1. In all, there were ten treatments replicated three times. The experimental field was laid out in 30 unit plots, each plot measuring 43.20 m^2 (7.2m x 6.0m). There were twelve rows of pigeonpea crop in each plot and twenty plants in each row. One row of crop from both sides of length and also both sides of breadth were left as guard rows. The net plot consisted of ten rows with eighteen plants per row (6.0 m x 5.4 m).

Seeds of pigeonpea variety TAT-9629 popularly known as PDKV- Tara were sown with the spacing of 60 cm between rows and 30 cm between plants on 8^{th} July 2016 and 28^{th} June, 2017. A fertilizer dose of 25 kg N, 50 kg P_2O_5 and 20 kg K_2O ha^{-1} through urea, single super phosphate and muriate of potash was applied at the time of sowing (basal application) to all the plots. Foliar application of gibberellic acid was done as per the treatments. For the foliar application of gibberellic acid a stock solution of 1000 ppm was prepared by using 1.1g gibberellic acid technical (90%) along with solvent dissolved in distilled water and made the volume to 1000 ml using volumetric flask and from this stock solution required amount of the gibbrellic acid as per the treatments was utilized for foliar application (Table 1).

Timely recommended plant-protection measures for pigeonpea crop were followed to save the crop from pests and diseases. The pigeonpea crop was harvested manually on 16^{th} January 2017 during first year and 15^{th} January 2018 during second year. Different growth and yield components were recorded periodically.

The data on various parameters recorded from experimental plots were statistically analyzed as suggested by Panse and Sukhatme (1995) by using 'F' test at P=0.05.

RESULTS AND DISCUSSION

Growth and yield parameters

The effect of foliar application of GA_3 on plant height in pigeonpea was found non- significant during both the years (Table 2). However, two applications of 75 ppm GA_3 at flowering and pod development stages recorded the highest plant height in pigeonpea (158.87 cm) during 2016 and two applications of 50 ppm GA_3 at flowering and pod development stages recorded highest plant height in pigeonpea (227.13 cm) during 2017, whereas no application of GA_3 (control) recorded the lowest plant height in pigeonpea (147.87 cm and 211 cm during, 2016 and 2017 respectively) during both the years.

Table 1: Treatment details

S.N.	Treatment details	Symbols used GA_3	Number of applications	Quantity of 1000ppm GA_3 stock solution utilized
1	Control (no application of GA_3)	T_1	Nil	Nil
2	Foliar application of 25 ppm GA_3 at Flowering	T_2	01	25ml/ liter water
3	Foliar application of 50 ppm GA_3 at Flowering	T_3	01	50ml/ liter water
4	Foliar application of 75 ppm GA_3at Flowering	T_4	01	75ml/ liter water
5	Foliar application of 25 ppm GA_3 at Pod development	T_5	01	25ml/ liter water
6	Foliar application of 50 ppm GA_3 at Pod development	T_6	01	50ml/ liter water
7	Foliar application of 75 ppm GA_3 at Pod development	T_7	01	75ml/ liter water
8	Foliar application of 25 ppm GA_3 at Flowering & Pod development	T_8	02	25ml/ liter water
9	Foliar application of 50 ppm GA_3 at Flowering & Pod development	T_9	02	50ml/ liter water
10	Foliar application of 75 ppm GA_3 at Flowering & Pod development	T_{10}	02	75ml/ liter water

Foliar application of GA_3 significantly influenced the pigeonpea branches per plant, pods per plant, seed index and grain yield per plant (Table 2 & 3). Two applications of 75 ppm GA_3 at flowering and at pod development stages recorded significantly higher number of branches /plant, number of pods/ plant, seed index and grain yield/ plant during 2016. However during 2017 these parameters were higher with the two applications of 50 ppm GA_3 at flowering and at pod development stages. Two applications of 75 ppm GA_3 during 2016, recorded 39% more branches, 46% more pods per plant, 4% heavier grains and 45% more grain yield per plant than that of control. Whereas during 2017, two applications of 50 ppm GA_3 recorded 44% more branches, 41% more pods per plant, 5% heavier grains and 68% more grain yield per plant than that of control. Improvement in growth parameters of pigeonpea crop is due to the application of different concentrations of GA_3 over untreated (control) is possibly due to the beneficial effects of GA_3 on cell elongation and cell division, increase in photosynthetic activity and better food accumulation. The foliar application of GA_3 at flower initiation and pod formation stage might have improved the reproductive development of pigeonpea crop and supported efficient translocation of photosynthates from source to sink. This might have significantly increased the number pods/ plant, grain mass and yield/ plant. Similar results were observed by Uddin (2001) and Akter *et al.*, (2007).

Grain and straw yield

Application of GA_3 significantly influenced the pigeonpea crop grain yield (Table 4). Two applications of 75 ppm GA_3 at flowering and at pod development stages recorded significantly higher grain yield (1970 kg ha^{-1}) and it was higher by 19% than control treatment (1654 kg ha^{-1}) in 2016. Whereas during 2017, two applications of 50 ppm GA_3 at flowering and at pod development stages recorded significantly higher grain yield (2128 kg ha^{-1}) and it was higher by 21per cent than control treatment (1765 kg ha^{-1}). The effect of exogenous application of GA_3 on straw yield of the pigeonpea crop was found non-significant during both the years (Table 4). Assimilate translocation to reproductive sinks is vital for seed development. Seed set and filling cab be limited by availability and utilization assimilates (Asch *et al.*, 2005).The grain yield of pigeonpea crop was increased due to cumulative effect of yield attributing characters, enhanced photosynthetic efficiency and improvement in the capacity of the reproductive sinks to utilize the incoming assimilates due to the exogenous application of GA_3. Our results are in agreement with the work of

Table 2:Effect of different treatments on anxicilary characters

Treatments	Plant height (cm)		No. of branches plant^{-1}	
	2016	2017	2016	2017
T_1	147.87a	211.00a	12.40b	15.28b
T_2	148.13a	211.67a	13.93b	17.26b
T_3	153.53a	217.13a	15.60a	20.01a
T_4	154.07a	216.67a	16.40a	19.89a
T_5	154.07a	214.33a	16.67a	18.97b
T_6	149.27a	221.33a	14.13b	20.00a
T_7	151.87a	216.13a	15.33a	19.89a
T_8	154.40a	221.67a	16.80a	19.95a
T_9	157.27a	227.13a	17.13a	22.07a
T_{10}	158.87a	225.33a	18.07a	20.84a
SEm$\pm$	4.83	5.64	0.97	0.94
CD (P=0.05)	NS	NS	2.89	2.79

Means followed by the same letter do not differ significantly at the 0.05 probability level

Table 3: Effect of different treatments on yield parameters of pigeonpea

Treatments	No. of pods plant^{-1}		Seed Index (g)		Grain yield plant^{-1} (g)	
	2016	2017	2016	2017	2016	2017
T_1	**150b**	206c	7.89e	7.97c	29.57c	35.0c
T_2	154b	227b	7.96d	8.19b	30.66c	41.8b
T_3	166b	258a	8.08c	8.27a	33.56c	49.9a
T_4	188a	243b	8.12b	8.27a	38.21b	46.4b
T_5	194a	209	8.16b	8.19b	39.55a	37.2c
T_6	158b	239b	8.11b	8.26b	31.99c	43.7b
T_7	158b	231b	8.12b	8.25b	32.08c	44.3b
T_8	202a	265a	8.19a	8.27a	41.33a	51.7a
T_9	204a	290a	8.21a	8.36a	41.94a	58.7a
T_{10}	208a	273a	8.22a	8.38a	42.81a	56.8a
SEm$\pm$	7.34	12.73	0.05	0.04	1.42	3.37
CD (P=0.05)	21.81	37.82	0.15	0.11	4.23	10.00

Means followed by the same letter do not differ significantly at the 0.05 probability level

Upadhyay and Ranjan (2015).

Harvest index

The effect of exogenous application of GA_3 on harvest index of the pigeonpea crop was found non-significant during both the years (Table 4). However, two applications of 50 ppm GA_3 at flowering and pod development stages recorded the highest harvest index (34.35%) in 2016 and two applications of 25 ppm GA_3 at flowering and pod development stages recorded the highest harvest index (33.19%) in 2017, whereas single application of 50 ppm GA_3 at pod development stage recorded the lowest harvest index (32.27%) in 2016 and control (30.07%) in 2017. The higher harvest index indicated that, GA_3 application accelerated assimilate supply to sink and better utilization of the incoming assimilates by the reproductive sinks, which is in agreement with the results of Akter *et al.* (2007).

Protein content and Protein yield

The effect of foliar application of GA_3 on protein content in pigeonpea grain (%) was found non- significant during both the years (Table 5). The effect of foliar application of GA_3 on protein yield (kg/ ha) was found non- significant during 2016. Whereas during 2017 protein yield (kg/ ha) was significantly influenced by the application of GA_3 (Table 5). Two applications of 50 ppm GA_3 at flowering and pod development stage recorded

Table 4: Effect of different treatments on grain and straw yield of pigeonpea

Treatments	Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})		Harvest Index (%)	
	2016	**2017**	**2016**	2017	2016	2017
T_1	1654b	1765b	3364a	4105a	33.03a	30.07a
T_2	1674b	1860b	3467a	4074a	32.59a	31.36a
T_3	1759a	2127a	3693a	4444a	32.38a	32.36a
T_4	1772a	1963a	3662a	4414a	32.62a	30.76a
T_5	1867a	1966a	3610a	4326a	34.17a	31.21a
T_6	1714a	1967a	360a	4100a	32.27a	32.43a
T_7	1728a	1855b	3580a	4023a	32.82a	31.58a
T_8	1895a	2073a	3642a	4187a	34.34a	33.19a
T_9	1926a	2128a	3755a	4475a	34.35a	32.22a
T_{10}	1970a	2124a	3981a	4455a	33.16a	32.28a
SEm$\pm$	69.31	72.70	240.02	116.08	1.76	0.92
CD (P=0.05)	205.90	215.97	NS	NS	NS	NS

Means followed by the same letter do not differ significantly at the 0.05 probability level

Table 5: Effect of different treatments on protein content, protein yield and rain water use efficiency of pigeonpea

Treatments	Protein content (%)		Protein yield (kg ha^{-1})		Rain water use efficiency (kg/mm/ha)	
	2016	**2017**	**2016**	**2017**	**2016**	**2017**
T_1	23.65a	23.56a	391a	416b	2.40b	1.75b
T_2	23.63a	23.54a	396a	438b	2.43b	1.84b
T_3	23.64a	23.56a	416a	501a	2.55a	2.11a
T_4	23.67a	23.58a	419a	463a	2.57a	1.95a
T_5	23.55a	23.46a	440a	461a	2.71a	1.95a
T_6	23.62a	23.52a	405a	463a	2.48b	1.95a
T_7	23.64a	23.56a	409a	437b	2.50b	1.84b
T_8	23.59a	23.52a	447a	488a	2.75a	2.05a
T_9	23.58a	23.50a	454a	500a	2.79a	2.11a
T_{10}	23.57a	23.50a	464a	499a	2.86a	2.11a
SEm$\pm$	0.18	0.18	16.81	17.66	0.10	0.07
CD (P=0.05)	NS	NS	NS	52.46	0.31	0.21

Means followed by the same letter do not differ significantly at the 0.05 probability level higher protein yield over control. The increase in the protein yield is correlated with the grain yield of the pigeonpea. The best treatment recorded the higher grain yield of pigeonpea and resulted in higher protein yield.

Rain water use efficiency (RUE)

Rain water use efficiency (kg/ mm/ ha) was significantly influenced by the application of GA_3 (Table 5) during both the years. Two applications of 75 ppm GA_3 at flowering and at pod development stages recorded higher rain water use efficiency (2.86 and 2.11 kg/ mm/ ha during 2016 and 2017, respectively). The lowest rain water use efficiency was observed with no application of GA_3 (2.40 and 1.75 kg/ mm/ ha during 2016 and 2017, respectively). The best treatment recorded 19% (2016) and 21% (2017) more rain water use efficiency than that of the control treatment. Our results clearly indicate that application of GA_3 resulted in enhancing the effective use of rainfall by the pigeonpea crop.

Economics

Economics of pigeonpea production was significantly influenced by the GA_3 application during both the years (Table 6). Two applications of 75 ppm GA_3 at flowering and pod development stages recorded significantly higher gross returns (Rs. 88660/-), which was higher by Rs. 14220/- than that of no application of the GA_3 (Rs. 74440/-) during 2016. Whereas in 2017, two applications of 50 ppm GA_3 at flowering and pod development stages recorded significantly higher gross returns (Rs. 101060/-), which was higher by Rs. 17200/- than that of no application of the GA_3 (Rs. 83860/-). The effect of application of GA_3 on net monetary returns of the pigeonpea crop was found non- significant in 2016, while single application of 50 ppm GA_3 at flowering stage recorded higher net returns (Rs. 75980/-) over control (Rs. 67710/-) in 2017. The benefit: cost ratio was higher with the two applications of 25 ppm GA_3 at flowering and pod development stages during both the years. Increased grain yield owing to application of GA_3 significantly increased the gross and net monetary returns. The results confirm the findings of Aziz *et al.* (2012).

Conclusion

Pigeonpea is mostly grown in rainfed areas, where lack of moisture during the reproductive phase, especially in regions where farmers grow medium-to-long duration varieties, often leads to a situation of terminal

Table 6: Economics of pigeonpea as influenced by different treatments

Treatments	Cost of cultivation ($x\ 10^3$ Rs ha^{-1})		Gross Monitory Returns ($x\ 10^3$ Rs ha^{-1})		Net Monitory Returns ($x\ 10^3$ Rs ha^{-1})		B:C ratio	
	2016	2017	2016	2017	2016	2017	2016	2017
T_1	21.28	22.15	74.44b	83.86b	53.17a	61.71b	3.50	3.78
T_2	21.75	23.52	75.32b	88.35b	53.58a	64.83a	3.46	3.76
T_3	22.13	25.03	79.17a	101.01a	57.03a	75.98a	3.58	4.03
T_4	22.45	25.77	79.72a	93.24a	57.28a	67.47a	3.55	3.62
T_5	21.94	23.62	84.03a	93.39a	62.09a	69.76a	3.80	3.95
T_6	22.09	24.75	77.13b	93.44a	55.04a	68.68a	3.49	3.77
T_7	22.40	25.58	77.78b	88.11b	55.38a	62.53b	3.47	3.44
T_8	22.42	24.26	85.28a	98.47a	62.86a	74.21a	3.80	4.06
T_9	23.05	25.70	86.67a	101.06a	63.62a	75.36a	3.76	3.93
T_{10}	23.69	27.02	88.66a	100.91a	64.96a	73.89a	3.74	3.73
SEm$\pm$	-	-	3119	3453	3049	3325	-	-
CD (P=0.05)	-	-	9265	10258	NS	9880	-	-

Market rates of pigeonpea grains @ Rs. 4500/- per quintal (2016) and Rs. 4750/- per quintal (2017) drought, affecting crop yield substantially. Results of our study indicated that GA_3 management practices are promising in controlling the decline in productivity of pigeonpea crop in rainfed areas.

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Preparation of Wine from Jamun: A transition for Doubling Farmer's Income

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ABSTRACT

Jamun wine production is an alternative fordeployment of highly seasonal (May to June), highly perishable underutilized jamun fruits with short storability (upto 2-3 days under ambient temperature). The exploitation of underutilized fruits of jamun can provide a solution to nutrition, livelihood and economic security of tribals by using available traditional wisdom as well as modern processing technology. Setting up of fruit wineries could result in the economic upliftment of thetribals by generating employment opportunities. Keeping this scenario in view an investigation was undertaken for preparation of jamun wine at Department of Fruit Science, College of Horticulture, Dr.PDKV, Akola during 2015-17 with objectives to prepare the wine from jamun fruit juice with the wine yeast (*Saccharomyces cerevisiae var. ellipsoideus*) as a transition for Doubling Farmer's Income. Amongst the combination tried for different levels of yeast and fermentation duration, treatment combination S_1F_3 (*Saccharomyces cerevisiae var. ellipsoideus* inoculated at 0.20 g/l for 21 days of fermentation) was found best in respect of TSS, anthocyanin content, ethyl alcohol and anti oxidant activity.Considering the findings of investigation and highest net monitory returns (5.86 B:C ratio) obtained from jamun wine production it could be concluded that, the appropriate combination of levels of yeast and fermentation duration is needed for quality jamun wine production.

The Prime Minister's vision of doubling farmer's income by 2022 is worth serious attention. This laudable objective could not only improve the well being of our farmers but can also be a trigger to boost agri-based manufacturing growth in rural India. The diversification to more productive and remunerative crops has become the new milestone to be achieved in Indian Agriculture. A shift in favour of horticultural crops as a more viable and attractive alternative is a part of such diversification drive and strategy. (Malhotra S.K., 2017). In India about 88819 thousand tonnes of fruits are produced annually (Anon., 2016).

But hardly 1.2% of this is utilised for processing and preservation and about 30-33% of the total production is wasted due to spoilage during handling, transportation and lack of cold storage facility (Baisya, 1980). In order to minimise postharvest losses and to avoid market glut, fruits are need to be effectively utilised in processing industry (Sahota and Sunil, 2006). Jamun is also one of the underutilized fruit which is highly seasonal (May to June), highly perishable and short storability (upto 2-3 days under ambient temperature), and due to less popularity this fruit is considered as an unexploited fruit crop in India. The exploitation of underutilized fruits can provide a solution to nutrition, livelihood and economic security of tribals by using available traditional wisdom as well as modern processing technology. Setting up of fruit wineries could result in the livelihood and economic security of tribal farmers by using available traditional wisdom as well as modern processing technology by generating employment opportunities.Eastern Vidarbha region *viz.,*Gadchiroli district of Maharashtra is a treasure of underutilized jamun fruits. If exploited properly, has the potential of transforming the economy of this tribal dominated region.

The world production of jamun is estimated at 13.5 million tonnes out of which 15.4 % is contributed by India (Anon, 2014). The Eastern Vidarbha, Melghat and Konkan region of Maharashtra are known to have large number of jamun trees. However, large quantities of jamun are lost either through rainfall or in sorting and grading to meet quality standards for fresh fruit export market, which could otherwise be used for wineprocessing. In India alone wastage of Jamun is 0.5 - 2MT. A large quantity of marketable surplus fruit is available in all jamun growing regions which need to be processed and converted into value added products (Patil*et al.*, 2012) like jamun wine.

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The fruit, its juice and the seed contain an alkaloid, jambosine and a glycoside called 'jamboline' or 'antimellin' (Chowdhury and Ray, 2007). The glycoside Jamboline is the main compound which helps in controlling the blood sugar level.There is a very high anthocyanin content in jamunfruits which attributes to its antioxidant and free radical scavenging activity.Wine is the oldest fermented product known to the mankind, mentioned in the ancient scripts. Wines have always been considered as safe and healthful drink, an important adjunct to the diet and moderate quantity of wine consumption has been found to lower the mortality from heart diseases. Since the wines are not distilled they have more nutrients like vitamins, minerals and sugars than the distilled beverages like beer, brandy and whisky. In addition to this, several therapeutic and medicinal values are found to associate with wines. The existence of alcohol and anti-oxidants in wine reduce a variety of human ailments especially the cardio vascular diseases (Joshi and Sharma, 2004). Wines contain antioxidants. The anti microbial activity found with wines is an added advantage.The present study is an attempt to focus on the qualitative parameters and it also comprehensively examines the cost and returns in the production of wine from this underutilized jamun fruit for doubling the farmer's income.

MATERIAL AND METHODS

The experiment consisted of levels of yeast (*Saccharomyces cerevisiae var.ellipsoideus*inoculated at 0.20 g/l, 0.25 g/l and 0.30 g/l) and fermentation duration (7, 14 and 21 days) which were replicated thriceusing Factorial Completely Randomized Design (FCRD). Wine is an alcoholic product obtained by fermentation of fruit juices with yeast. The procedure was followed for the preparation of jamun wine as outlined by(Joshi 1995) at Department of Fruit Science, College of Horticulture, Dr.PDKV, Akola during 2015-17.Jamun fruits were washed, sorted, graded and selection of jamun fruits suitable for preparation of wine was done. The fruits were allowed to be crushed manually for the extraction of juice. The extracted juice was allowed to filter through muslin cloth and clear juice was used for fermentation. Adjustment of Total Soluble Solids was done to 24°B by adding cane sugar using digital refractometer (make ATAGO Model No. RX 7000X) and similarly pH was also adjusted to 3.5 by adding tartaric acid with Digital pH meter (make SYSTRONICS Model No. 335). Addition of sodium bicarbonate to the juice @ 100 ppm per litre was done to inhibit the growth of wild yeast and other spoilage microorganisms and also to prevent browning of jamun juice due to oxidation. This prepared jamun juice was treated as 'Must'.

For the setting of fermentation unit it was done using a very low cost locally available technology, the juice was taken in a flask up to 3/4th of its volume and the measured quantity of yeast was then added to the must under aseptic conditions as per the treatment details *i.e.* inoculation of *Saccharomyces cerevisiae var.ellipsoideus* at S_1 - 0.20 g/l, S_2 - 0.25 g/l and S_3 - 0.30 g/l.The flasks were

Fig. 1 : Manual crushing of Jamun fruits for Juice extraction

Fig. 2 : View of fermentation unit for jamun wine

connected to another 100 ml conical flask half filled with water. The two flasks are connected through a transparent tube to allow the passage of bubbles to be visible and plugged with cork having hole at the centre to connect with the water flask through the transparent tube. The tube was tightly sealed with the help of wax to avoid passage of air in the water flask which was then allowed for fermentation. The process of fermentation was monitored to the extent of bubbling. The bubbling starts as the fermentation process get started and stops as the process of fermentation get completed. Fermentation was completed when no more bubbles were coming out and was also ascertained by stabilization of TSS for two successive days. TSS normally comes to 7 ^{0}Brix or to 8 ^{0}Brix from initial level of 24°B. Fermentation was completed when no more bubbles were coming out followed by filtration, clarificationwith aid of clarifying agents such as bentonite @ 0.4 g/l to recover crystal clear wine of good quality, siphoning/racking, After clarification, the clear wine was siphoned off and transferred to hot sterile bottles, corked and subjected for pasteurization at 65°C for 30 minutes After cooling the bottles were stored for ageing in cold storage (14 ±1°C) during the period of investigation. During ageing, the jamun wine was racked regularly. Samples from the prepared clear jamun wine were analyzed at 9 months of ageingand also evaluated organoleptically after nine months of ageing with a panel of judges for their quality evaluation and acceptability.

The observations regarding the total soluble solids, ethanol, antioxidant activity and anthocyanin content of jamun wine was taken at interval of 3 months from fresh jamun wine till 9 months aged jamun wine. The Total Soluble Solids (TSS) was determined using Atago make RX 1000 digital refractometer. Ethyl alcohol content of wine was estimated by using specific gravity(Ranganna, 1979). The anthocyanins in wines were measured by slight modification in method suggested byJoshi *et al.*, 2012. Anthocyanin content was expressed in terms of absorbance units at 530 nm (A-530 nm) per ml of wine. The antioxidant Activity in Jamun wine was estimated by Diphenyl-p-picrylhydrazyl (DPPH) method described byManzocco*et al.* (1998). The cost benefit ratio was calculated by following the procedure given by David *et al.*, 2013.

RESULTS AND DISCUSSION

The data regarding TSS and anthocyanin content of jamun wine as influenced by yeast levels and fermentation duration at final stage of ageing i.e., 9 months aged jamun wine is presented in Table 1.

The data regarding the pooled mean of two years i.e., 2015-16 and 2016-17, clearly indicated that the treatment combination S_1F_3 was found significantly superior amongst all treatment combinations. At 9 months of ageing significantly minimum Total Soluble Solids (4.29 °B) and maximum anthocyanin content (65.03 mg/100ml)

Table 1. Effect of yeast levels and fermentation duration on Total Soluble Solids and anthocyanin of 9 months aged jamun wine

Treatment	Pooled Mean of two years data (2015-2017)							
	TSS (°B)				Anthocyanin (mg/100ml)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
S_1	6.09	5.28	4.29	5.22	47.14	34.15	65.03	48.77
S_2	5.56	5.62	4.98	5.60	52.25	32.86	59.12	48.07
S_3	5.34	6.25	5.00	6.08	41.71	54.27	55.46	50.48
Mean	5.66	5.72	4.76		47.03	4.042	59.87	
	S	F	SXF	S	F	SXF		
'F' test	Sig	Sig	Sig	Sig	Sig	Sig		
SE (m) ±	0.096	0.096	0.166	0.182	0.182	0.315		
CD at 5%	0.287	0.287	0.498	0.545	0.545	0.944		

were recorded with treatment combination S_1F_3 (*Saccharomyces cerevisiae var.ellipsoideus* inoculated at 0.25 g/l @ 21 days of fermentation). However maximum TSS (6.25 °B) was recorded in treatment combination S_3F_2 (*Saccharomyces cerevisiae var.ellipsoideus* inoculated at 0.30 g/l @ 14 days of fermentation) and minimum anthocyanin content was recorded as 32.86 mg/100ml in the treatment combination S_2F_2 (*Saccharomyces cerevisiae var.ellipsoideus* inoculated at 0.25 g/l @ 14 days of fermentation). It was also observed that the anthocyanin content was decreased with increase in ageing whichcould be attributed to the combined effect of thermal degradation, oxidative degradation and condensation reactions with other phenolic compounds such as flavanols and hydroxyl cinnamates (Ribereau-Gayon*et al.*, 2000; Beer *et al.*, 2005).

From the above results it can be summarized that minimum TSS and maximum anthocyanin content which is considered desirable for quality jamun wine production was achieved with lowest yeast level and larger fermentation duration *i.e.*, *Saccharomyces cerevisiae var.ellipsoideus* inoculated at 0.25 g/l @ 21 days of fermentation. Decrease in TSS might be due to precipitation of soluble solids during interaction of various components which might have resulted in a decreased TSS during maturation (Sharma *et al.*, 2009, Joshi *et al.*,

Fig. 3 : View of jamun wine bottle

Table 2. Effect of yeast levels and fermentation duration on ethyl alcohol and Antioxidant activityof 9 months aged jamun wine

Treatment	Pooled Mean of two years data (2015-2017)							
	Ethyl alcohol (%)				Antioxidant activity (% DPPH)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
S_1	7.58	9.24	9.60	8.81	79.69	82.31	86.32	82.77
S_2	8.86	9.43	9.53	9.27	81.40	83.22	86.34	83.66
S_3	8.61	9.41	9.54	9.18	81.69	81.09	85.05	82.61
Mean	8.35	9.36	9.51		80.93	82.21	85.90	
	S	**F**	**SXF**	**S**	**F**	**SXF**		
'F' test	Sig	Sig	Sig	Sig	Sig	Sig		
SE (m)±	0.088	0.088	0.153	0.119	0.119	0.206		
CD at 5%	0.264	0.264	0.458	0.356	0.356	0.617		

Table 3: Net profit and Cost benefit ration for Jamun wine production

Items of Marketing Cost	Cost per Bottle(In Rs.)	Cost per liter(In Rs.)
Production cost (A+B)	69.079	92.10
Capital recovery cost (C)	7.67	10.23
Total production cost D = (A+B+C)	76.75	102.34
Marketing Cost	219.39	292.53
Total Cost	296.15	394.87
Gross Returns (E)	450.00	600.00
Net Profit	161.53	215.36
CBR (F=E/D)	1:5.86	1:5.86

2014). Similar findings have been reported by Joshi *et al.* (2012a) in jamun wine andJoshi *et al*., (2013) in grape wine.

The data regarding ethyl alcohol and antioxidant activity as influenced by yeast levels and fermentation duration at final stage of ageing i.e., 9 months aged jamun wine is presented in Table 2.

Regarding the interaction effects of level of yeast and fermentation duration in pooled mean of two years data, maximum ethyl alcohol content (9.60 %) was recorded by wine with treatment combination S_1F_3 (*Saccharomyces cerevisiae var.ellipsoideus* inoculated at 0.20 g/l @ 21 days of fermentation) which was found at par with S_1F_2 (9.24 %), S_2F_2 (9.43 %),S_3F_2 (9.41 %), S_2F_3 (9.53 %)and S_3F_3 (9.54 %). Whereas, minimum ethyl alcohol content (7.58 %) was registered under the treatment combination S_1F_1 (*Saccharomyces cerevisiae var.ellipsoideus* inoculated at 0.20 g/l @ 7 days of fermentation).

The increase in the ethyl alcohol content of the jamun wine might be attributed to the fact that, the alcoholic fermentation carried out with *S. cerevisae*strain revealed consumption of sugar causing decrease in TSS with time or it might be due to the higher levels of reducing sugars which are more readily fermentable giving rise to higher levels of alcohol Gautham and Chundawat (1998). It has also been observed that as the alcohol content increases in the wine, the content of the TSS and microbial count decreases. (Kocher *et al.,* 2011).

In pooled mean of the two years data maximum antioxidant activity was recorded fromS_2F_3 (86.34 % DPPH) which was found at par with S_1F_3 (86.32 % DPPH) whereas minimum antioxidant activity was noted from S_1F_1 as 79.69 % DPPH. The reason for decrease in total antioxidant activity could be the decrease in total phenol content during bottle ageing of red wines. The underlying changes in the individual phenolic groups are, however, also likely to play a contributory role in the decreased antioxidant activity of the wines (Beer *et al.,* 2005).

Cost Analysis

The cost benefit ratio is an important tool to assess economics of farming. The cost benefit framework is essential a modular partial equilibrium model, with demand and supply relationships that can be calibrated to empirical data and allowing the calculation of economic welfare effects. The table 4 shows net return and cost benefit ratio of wine industry. Per year average 3,00,000 liters of processed wine and the average wholesale market price of per liter is Rs. 600/-. For computing the total returns from wine is per bottle Rs. 450/-, per literRs. 600/- and wine industry is Rs. 18,00,00,000/-. By deducting the total cost of per bottle Rs. 296.15/-, per literRs. 394.87/- and average cost of wine industry is Rs. 11,84,62,269/-, the net profit comes to about per bottle Rs. 161.53/-, per literRs. 215.36/- and wine unit is Rs. 6,15,37,731/-. The cost benefit ratio of wine is 1: 5.86. It is definitely an encouraging return to the wine producer.

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Development and Field Evaluation of Innovative Solar Photovoltaic Insect Light Trap

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ABSTRACT

A solar insect light trap was developed consisted of 10 W SPV panel, 12 V; 7 Ah lead acid battery, charge controller, dusk to down electrical circuit and adjustable stand. As per design calculations the trap was fabricated in the workshop. The performance of solar photovoltaic insect light trap installed in the farmer's field (Maharashtra), was evaluated for insect trapping during night hours. The performance of the solar photovoltaic insect light trap was evaluated in the cotton field for finding out the efficiency of the developed solar insect light trap. The average values of ambient temperature, wind velocity, panel temperature, solar intensity, panel output, panel efficiency, panel voltage, panel current, exergy efficiency of panel and battery voltage in different color light trap viz., blue, yellow and UV-A blue were recorded. The total number of insects caught in blue, yellow and UV-A blue color light were 6820, 8199 and 19872, respectively during the experimentation. The order wise and daily distribution of insects in blue color light, the highest population of Lepidopteraan insects was observed. It could be inferred that the solar insect light trap was technically as well as economically feasible.

The demand for energy is growing day by day in the whole world. The Conventional energy sources like coal and petroleum are limited. Renewable energy resources will play an important role in the future. Agriculture is a principal occupation in India and more than 70 % peoples are involved in agriculture. Insect pests are the major problem to the farmers greatly reducing their income by destroying the field crops. There ismuch prevention and exterminations for pest problems, such as physical, biological, chemical and mechanical methods are controlling the insect pests. This causes plant residue which is dangerous for consumers and when consuming the fruits and vegetables gives us major problems to the health (Brimapureeswaran 2016). Maharashtra has 40 lakh hectares and which is 35% of the total cultivable area in state under cotton crop. The main or major phototropic insect pests of cotton that cause economic loss to this crop are cotton jassid, cotton whitefly, Armyworm, Cotton Mealy Bug, American bollworm, Pink bollworm and other (Muhammad 2017).

Light becomes visible to insects around the yellow part of the spectrum and ends at ultraviolet light. (Ashfaq*et al.*, 2005) Reducing and controlling the pest population using light traps is an age old practice. Though several models and designs of insect light trap are available but according to (Reddy *et al.*, 2015) solar powered trap with collecting net, which has not dependent on any other source like wind power, mechanical power, fuel and electricity. This device operates automatically, turning on the light during night hours and turned off before sunrises. Every year farmers are facing problems due to pest attack which seriously destroy their crops and thus reduce their income. In Vidarbha and other region of Maharashtra, cotton crop has been grown predominantly as a cash crop. Vidarbha and Marathwada regions of Maharashtra are staring at huge losses owing to a pest (pink bollworm) attack on the cotton crop, across at least eight lakh hectares of land in 20 districts. More than 96% farmers use BT cotton seeds, which were supposed to be averse to the attack of pink bollworm and thus cotton production was reduced drastically. The farmers are using costly pesticides but the bollworm was found resistant to the chemicals available in the market. Hence the integrated pest management techniques for pest control use of pheromone trap, yellow sticky trap, electrically operated light trap etc. was suggested. One of the limitations of electrically operated light trap use on the farmer's field in the unavailability of electricity in each and every field. In Indian villages, availability of electricity is a major constrain and almost absent in remote villages (Bhamre*et al.*, 2005) along with higher cost of electricity or electrically based light traps.

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Methodology

Development of solar photovoltaic insect light trap

This system is mainly consisted of solar panel, sealed lead acid battery, charge controller, relay circuit, LED light, bulb holding funnel, insect collecting chamber, battery box and adjustable three leg support base frame (Bela, 2015).

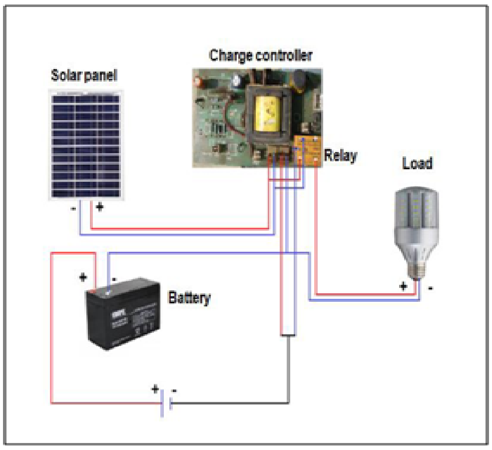

Fig. 1 Circuit arrangement of solar

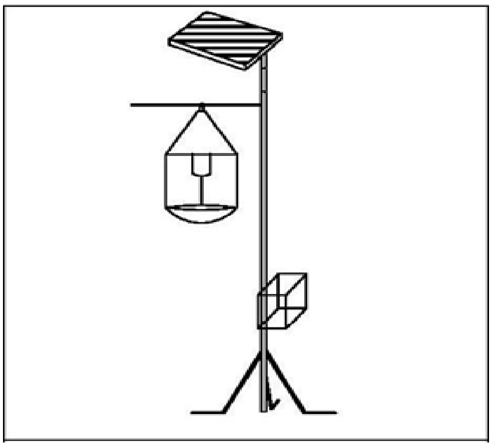

Fig.2 Solar insect light trap photovoltaic insect light trap

Table 1 Details of solar photovoltaic insect light trap components

S. N.	Components	Details	Specifications
1	Photovoltaic panel	Multi crystalline Silicon Solar cells used in the photovoltaic panel for the solar insect light trap to generate sufficient voltage to charge the battery with exposure to sunlight	10 Wp
2	Sealed lead acid battery	Battery is a source of stored electrical energy or it is called as storage cell battery, means it can store electrical energy and give whenever requires.	12 V and 7 Ah
3	Charge controller	A charge control unit prevents the reverse flow of current from battery to panel and also protects battery from overcharging	5 A
4	Relay circuit	relay is used to turn on by sunset and turn off after sunrise and it is a continuous operation	12 V and 10 A
5	LED light	A 5-watt blue and yellow LED strip bulb having 3 bulbs on each strip and total of 30 bulbs were used. One 5W ultra violet light having 16 bulbs on each line and total 48 of bulbs were joined to make a unit as a single bulb. Hence to attract the insect UV-A blue LEDbulb, blue LEDbulb and yellow LEDbulb were used	5 watt
6	ON/OFF switch	It used to ON or OFF the complete system	
7	Bulb holding funnel	It was hanged over the stand with the help of iron angle and holds the bulb assembly	Upper dia.: 30 cm Lower dia.: 5 cm
8	Insect collecting chamber	It acts as a collection unit for insect which was hanged to the bulb holding funnel	Diameter: 38 cm
9	Battery box	It holds the battery, solar charge controller, relay, ON/OFF switch, power outlets and input in the same box.	22 cm × 18 cm
10	Adjustable three leg support based frame	It was provided with adjustable screw to maintain the height of bulb according to crop height	Length: 153 cm Height: 98 cm

figg. 3 Field performance of solar photovoltaic insect light trap

Fig 4: Evaluation of solar light trap at farmers field

Energy analysis

The performance of a PV module was expressed in terms of its current, voltage and power-voltage characteristic and which is a function of solar radiation and module temperature, photovoltaic and exergy efficiency.

Evaluation of light trap using different color LED bulbs for trapping phototrophic insects

The experiment was conducted by using solar photovoltaic operated light trap with three colored LED having 5 Watt power rating bulb viz., blue, yellow, and UV-A blue. All three light traps were installed at 2 feet above the crop height and 30 meter apart from each other to let the insect to orient toward their most favorite color. Light traps were operated from 19.00 hrs to 22.00 hrs and 4.00 hrs to 6.00 hrs daily numbers of insects caught were recorded and the insects were separated order wise. Fig. 4 & 5 depicted the evaluation of trap at farmer's field. The evaluation of the solar light trap in relation to the crop condition is shown in the Fig. 5.

Order wise comparison of the insects caught in the above mentioned light traps

The insects collected by the above mentioned light traps were sorted out order wise and tabulated to know the effect of light on the attraction of insect.

Economic feasibility of solar photovoltaic insect light trap

The economic feasibility of solar insect trap was calculated by using discount rate method.

Following different economic indicators were used for economic analysis of solar system under this study (El-Nashar, 2000):

1) Net present worth (NPW)
2) Benefit cost ratio (B/C ratio)
3) Payback period

Results and Discussion

Results obtained during experimentation are discussed in following subsection.

Performance evaluation of SPV insect light trap

The comparative performance of solar photovoltaic insect light trap of the three color LED light viz., blue, yellow and ultra violet-A blue were evaluated and the results obtained are discussed.

Performance of solar photovoltaic system

The variation of solar intensity and corresponding power from solar panel was recorded for the consecutive days in March when solar insect light trap was kept in cotton field (Bhubneswari*et al*., 2011).

From the above results it was observed that the power developed by SPV panel increased with respect to

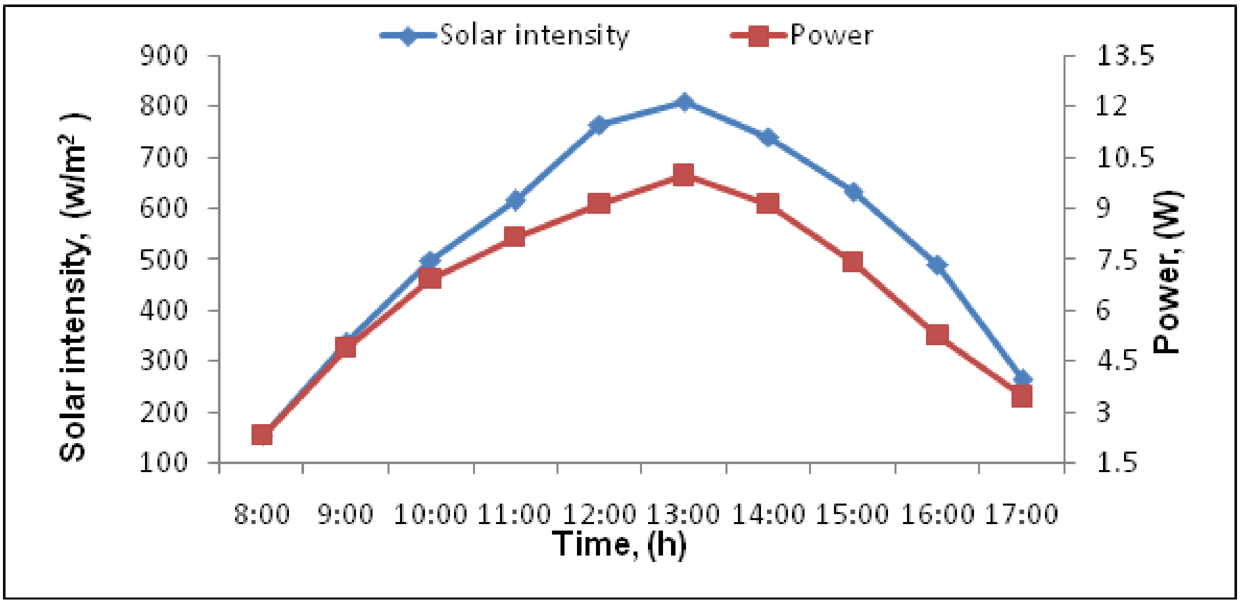

Fig. 5. Variation in solar intensity and power output of solar panel with time

increase in solar radiation. It was revealed that, the power generated by selected solar panel was suitable for solar photovoltaic insect light trap. The V-I and power characteristics of the 10 W solar panel were carried out at normal condition on clear sunny day to determine the maximum current and maximum voltage with respect to time. The typical V-I characteristic's curve of solar panel of light trap is shown in Fig.5.

It was revealed that, the selected panel is suitable in terms of current, voltage and power supply to the solar photovoltaic insect light trap. Fig. 6 gives the variation in panel efficiency, exergy efficiency and solar intensity with respect to time.

Evaluations of light trap using different colour LED light for trapping phototrophic insects

Table 3 represents the percentage of the total number of insects caught in various coloured light traps. According to the percentage of insects collected, the lowest number of insects were attracted towards blue colour light i.e. 19.54%. This finding is in accordance with Ashfaq*et al.*, 2005 and Pate and Curtis (2011) who also found that the lowest numbers of insects were trapped in blue colored light among the various coloured lights tested. Ultra violet light attracted the highest number of 56.95% insects. Yellow light was rated second in attracting the insects (23.49%).Percentage of insects attracted

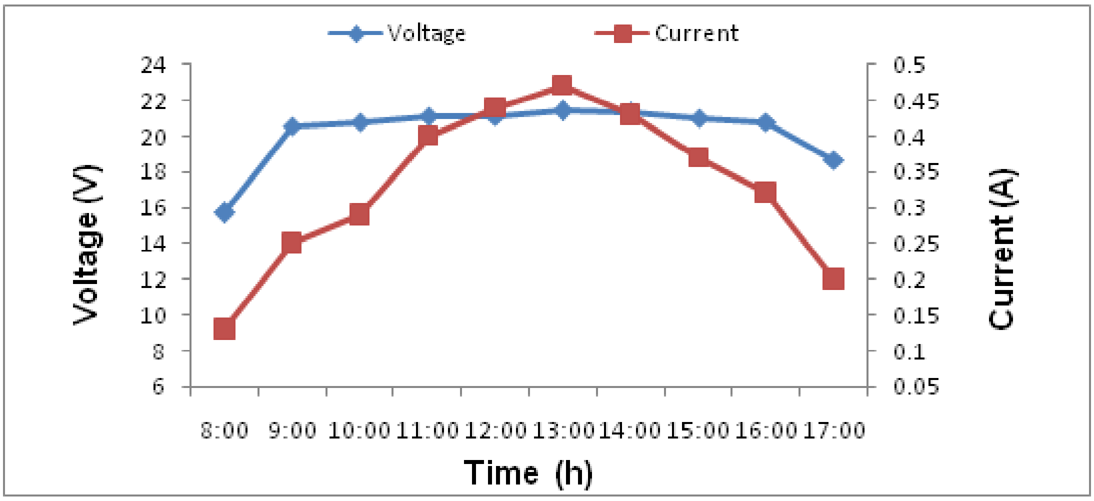

Fig. 6.Variation in current and voltage of solar panel with time

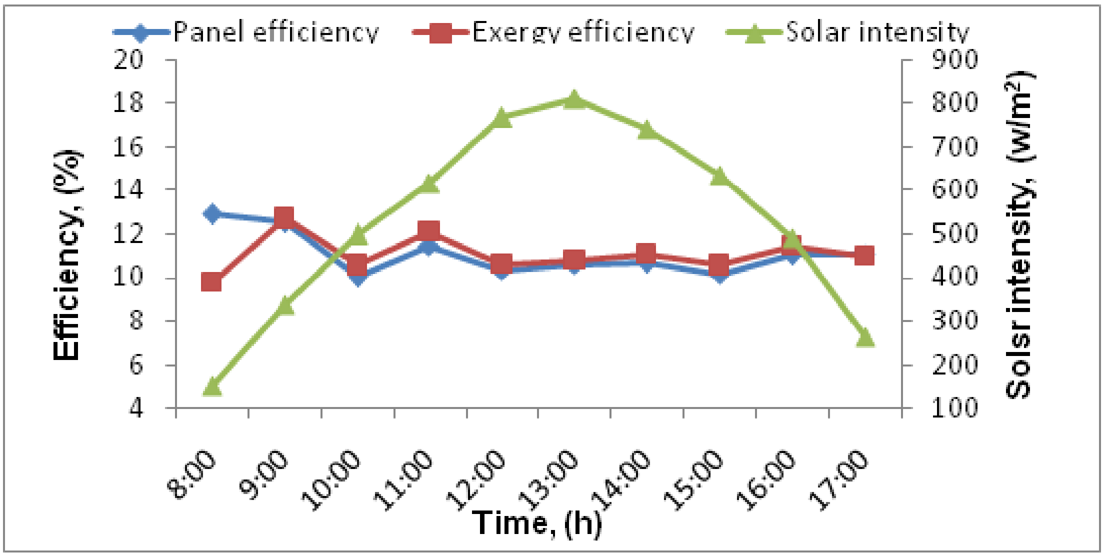

Fig. 7.Variation in panel efficiency, exergy efficiency and solar intensity with time of solar insect trap

towards different coloured light was computed separately and tabulated in Table 4.

Table 3: Percentage of insects attracted in different light trap

S.N.	Colour of light	Insect population percent (%)
1.	Ultra violet	56.95
2.	Yellow	23.49
3.	Blue	19.54

Use of ligh trap for collecting harmful insect is one of the tool in IPM. Among all three light traps, the performance of UV-A blue light insect trap was found better in terms of insect collected. Most of the harmful insects were attracted towards UV-A blue light and hence it is calculated that the use of UV-A blue light in solar insect trap is beneficial in integrated pest management practices (Bhamre *et al.*, 2005).

Table 4: Percentage of insects attracted in blue light, Yellow light and UV light

S.N.	Order	Insect population percent (%)		
		Blue light	Yellow light	Ultraviolet light
1.	Hemiptera	50.52	50.28	51.92
2.	Lepidoptera	44.36	44.77	41.00
3.	Diptera	4.85	4.72	6.96
4.	Coleoptera	0.24	0.21	0.10

Table5: Performance of solar insect trap using blue light

Insect order	Insect name	Time (hrs)				Total insect collected in blue light trap
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	1	2	0	0	3
	Aphides	24	37	12	12	85
	Whitefly	8	27	11	17	63
	Leaf hopper	2	7	0	0	9
	Dusky cotton bug	1	3	1	0	5
Lepidoptera	Leaf miner	7	11	2	8	28
	Pink bollworm	29	42	36	7	114
	American bollworm	04	26	12	12	54
Coleptera	Lady bird beetle	0	1	0	0	1
Mean				**362**		

Table 6 : Performance of solar insect trap using yellow light

Insect order	Insect name	Time (hrs)				Total insect collected in yellow light trap
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	0	3	1	0	4
	Aphides	50	62	54	5	171
	Whitefly	21	46	16	8	91
	Leaf hopper	8	15	0	0	23
	Dusky cotton bug	2	5	1	0	8
Lepidoptera	Leaf miner	3	13	8	12	36
	Pink bollworm	09	32	10	3	54
	American bollworm	11	38	9	13	71
Coleptera	Lady bird beetle	1	1	0	0	2
Mean						460

Table7:Performance of solar insect trap using UV light

Insect order	Insect name	Time (hrs)				Total insect collected in UV light trap
		19-20	20-21	21-22	04-06	
Hemiptera	Red cotton bug	6	8	0	4	18
	Aphides	42	82	13	14	151
	Whitefly	21	102	38	86	247
	Leaf hopper	12	10	4	0	26
	Dusky cotton bug	12	16	8	3	39
Lepidoptera	Leaf miner	9	42	21	12	84
	Pink bollworm	14	98	25	71	208
	American bollworm	32	72	32	44	180
Coleptera	Lady bird beetle	0	0	0	0	0
Mean						953

Performance evaluation of solar insect light trap

The experiment was conducted by using three 5 watt light viz. blue, yellow and ultra violet. All Three light traps were installed as per crop height from the ground level and solar insect light trap was installed at specific intervals from each other to let the insect towards the trap. Solar insect light trap was operated from 7p.m. to 10.00 p.m. and 4.00 am to 6.00 am daily and type wise separation and number of insects caught was recorded as given in table 5,6,7.

Economic feasibility of solar photovoltaic insect light trap

The economic feasibility of the solar photovoltaic insect light trap was evaluated using discount cash flow (DCF) method (Table 8). The economic parameters viz., present worth of cost, present worth of benefit, net present value and payback period was determined.

Table 8 : Parameters used to analyses the economic feasibility of solar photovoltaic insect light trap

S. N.	Costs	SPV trap	Electrical trap
1.	Capital cost, Rs.	6000	3800
2.	Maintenance Cost, Rs.	600	600
3.	Electricity charge, Rs.	Nil	2856

The net present value for the 12year of cash flow analysis was found to be Rs.9371.69/-. The benefit cost ratio of the financial system has been worked out for the cost and benefit involved over the period. The benefit cost ratio of the solar photovoltaic insect light trap was observed to be 1.93 with payback period of 2 year 1 month

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Influence of Rotational Speeed and Feed Rate on Fennel Seed Extraction Efficiency

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ABSTRACT

Spices seed extractor was developed during 2015-18 to extract the seeds from fennel plant and flowers. The spices seed extractor was operated by 2 hp single-phase electric motor. The developed spices seed extractor consist of feeding hopper, extraction unit, sieve/cleaning unit, main frame and power transmission system. Machine and operational parameters were optimized for fennel seed extraction to achieve higher seed extraction efficiency. The optimized machine and operational parameters for fennel seed extraction were found to be stud bolted type drum having rotational speed of 700 rpm and feed rate of 170 kg/h for maximum seed extraction efficiency. The seed extraction efficiency was found to be 96.36 per cent at optimized machine parameters.

India is the second largest vegetable producer, producing 99.4 million tones of different vegetables. The application of suitable seed extractor in the advancement of extraction process will facilitate production of healthy seed and will set higher standards for various parameters (Khushwaha, 2005). Fennel is considered to be one of the most important medicinal and aromatic plants. Fennel can be used as antispasmodic, carminative and for the relief of epigastric pain, intestinal cramps and colics especially for infants. Its roots are also used as laxative and diuretic. Fennel oil is used in manufacturing of condiment, perfumes, soap and as a food flavor. Commercial fennel varies greatly in quality, this being either due to lack of care in harvesting or deliberate adulterate. It may contain dust, stem tissues, weed seeds and other materials.

Seed extraction/separation and cleaning is an important operation in a number of processes connected with the handling of seed after harvest. It is impossible to grow and harvest seed crops without getting undesirable intermixtures despite proper care and tending of the crop. These intermixtures may comprise weed seeds, other crop seeds, and various inert matter as well as undeveloped seeds of species in question.

Traditional method of seed separation/extraction involve various operations like harvesting, sun drying, beating and winnowing. It takes more time and seed obtained by this method is of poor quality. Also presently no mechanical extractor is available for extraction and cleaning of fennel seed. The spices seed extractor was developed for extraction of spices such as fennel seeds mechanically. It was necessary to study the influence of input parameters. Hence, the work was undertaken to optimize the input parameters for maximum extraction efficiency.

MATERIAL AND METHODS

The fully matured fennel crop with well dried flowers of variety AF 101 available at the field of Chilli and Vegetable Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola were used for conducting the experiments on fennel seed extraction .

Spices seed extractor

The spices seed extractor was developed in the workshop of AICRP on Post Harvest Engineering and Technology and Department of Agricultural Process Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola and was used for the extraction of fennel seeds. The spices seed extractor consisted of the following major units viz., i) Feeding hopper ii) Seed extraction unit iii) Sieve/Cleaning unit iv) Main frame and v) Power transmission system.

Plate 1. Spices seed extractor

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Optimization of parameters for extraction of ajwain seeds

Three types of extraction drums were fabricated for the experiments. The developed spices seed extractor was tested as per standard procedures for combination of various treatments. Based on feeler trials, some of the machine and operational parameters such as concave clearance, sieve aperture size and blower/fan speed were finalized for fennel crop and were kept constant throughout the complete experimentation. Experiments were conducted to optimize the design parameters such as type of seed extraction mechanism (stud bolted drum, loop type drum, leather flap drum) and the operational parameters such as rotational speed and feed rate. Fennel crop samples each weighing 2 kg and having about 10 ± 0.5 % moisture content (w.b.) were used for extraction using the developed spices seed extractor. After seed extraction all the fractions at each outlet were collected in the separate containers. Each of the sample was analyzed for extracted seed, unextracted seed, chaff, etc. Care was taken to obtain all the fractions without any loss.

The variables of seed extraction experiments were optimized using Response Surface Methodology technique, since this is useful statistical technique for investigation of complex processes. The studies of optimization have been carried out by various research workers (Pokharkar, 1994; Vijayan and *et al.*, 1995; Chowdhary *et al.*, 2000; Kar and Gupta, 2001; Liyana-Pathirana and Shahidi, 2005; Eren and Kaymak-Ertekin, 2007; Jain, 2007; Altan *et al.*, 2008; Corzo *et al.*, 2008; Mestdagh *et al.*, 2008; Shi *et al.*, 2008 and Borkar, 2011).

Optimization of Seed Extraction Unit

The type of seed extraction drum, rotational speed and feed rate were optimized for maximum extraction efficiency and minimum seed damage.

Treatment Details

Independent variables

Categoric factors

Types of seed extraction drums-Stud bolted drum ii. Loop type drum iii. Leather flap drum

Rotational speed of seed extraction drum (R), rpm - 600 ii. 650 iii. 700 iv. 750 v. 800

Feed rate (F), kg/h - 60 ii. 120 iii. 180 iv. 240 v. 300

Dependent variable

i. Extraction efficiency

The extraction efficiency was calculated using the following formula.

Extraction efficiency, % = 100 – un-extracted seed

$$\text{Unextracted seed (\%)} = \frac{\text{Weight of unextracted seed, g}}{\text{Weight of total seed input, g}}$$

Optimization of seed extraction drum for fennel seed extraction

The experimental layout for two variable five levels response surface analysis as shown in Table 1 was used.

Design of experiments

Response Surface Methodology (RSM) was applied to the experimental data using Design-Expert version 9 (Statease Inc, Minneapolis, USA, Trial version, 2017). The Central Composite Design of two variables and five levels including thirteen trials was used for each type of extraction drum. As per this design, total 39 trials were performed for all the three type of seed extraction drums.

Table 1. Levels of independent variables for fennel seed extraction

Independent variables	Symbols		Levels	
	Coded	Decoded	Coded	Decoded
Rotational speed, rpm	x_1	X1	2	800
			1	750
			0	700
			-1	650
			-2	600
Feed rate, kg/h	x_2	X2	2	300
			1	240
			0	180
			-1	120
			-2	60

RESULTS AND DISCUSSION

During preliminary experiments, extraction efficiency was found to be dependent on the machine and operational parameters. Based on feeler trials, concave clearance and blower/fan speed were finalized and were kept constant throughout the complete experimentation. Moisture content at the appropriate time of extraction was measured and was in the range of 10 ± 0.5 per cent on wet basis.

Effect of variables on fennel seed extraction efficiency

The results obtained during the experimentation on fennel seed extraction using the developed spices seed extractor are revealed that the extraction efficiency was observed to be ranging from 84.55 to 96.82 per cent depending upon the extraction treatments. The maximum extraction efficiency was observed in case of treatment having the combination of stud bolted drum, rotational speed of 700 rpm and feed rate of 180 kg/h. The minimum seed extraction efficiency was found for treatment having the combination of leather flap drum, rotational speed of 800 rpm and feed rate of 300 kg/h. The fennel seed extraction efficiency was found to be dependent on the type of seed extraction drum, rotational speed and feed rate.

The data for extraction efficiency were analyzed for stepwise regression analysis and the analysis of variance (ANOVA) is shown in Table 2. The response surface reduced cubic model was fitted to the experimental data and statistical significance for linear, interaction and quadratic effects were analyzed for extraction efficiency which gives the effect of various parameters on extraction efficiency.

For fennel extraction efficiency, the model F-value of 21.86 implies that the model is significant ($P<0.01$). The linear terms (R and F) are significant ($P<0.01$). The lack of fit F-value was non significant, which indicates that the developed model was adequate for predicting the response. Moreover, the predicted R^2 of 0.7170 was in reasonable agreement adjusted R^2 of 0.9032. This revealed

Table 2: ANOVA for effect of variables on fennel seed extraction efficiency

Source	Sum of Squares	df	Mean Square	F-value	p-valueProb>F	
Model	443.20	17	26.07	21.86	< 0.0001	significant
A-Speed	3.71	1	3.71	3.11	0.0925	
B-Feed rate	0.0800	1	0.0800	0.0671	0.7981	
C-Type of roller	252.61	2	126.30	105.91	< 0.0001	
AB	0.4840	1	0.4840	0.4058	0.5310	
AC	0.3982	2	0.1991	0.1669	0.8474	
BC	0.1237	2	0.0619	0.0519	0.9496	
A^2	50.95	1	50.95	42.72	< 0.0001	
B^2	141.71	1	141.71	118.82	< 0.0001	
ABC	0.5391	2	0.2696	0.2260	0.7996	
A^2C	1.37	2	0.6845	0.5740	0.5719	
B^2C	11.23	2	5.62	4.71	0.0204	
Residual	25.04	21	1.19			
Lack of Fit	16.83	9	1.87	2.73	0.0538	not significant
Pure Error	8.21	12	0.6845			
Cor Total	468.24	38				
Std. Dev.	1.09	**R^2**		0.9465		
Mean	89.56	**Adjusted R^2**		0.9032		
C.V. %	1.22	**Predicted R^2**		0.7170		
PRESS	132.52	**Adeq Precision**		14.9636		

that the non-significant terms have not been included in the model. Therefore, this model could be used to navigate the design space. High value of coefficient of determination ($R^2 = 0.9465$) obtained for response variable indicated that the developed model for extraction efficiency accounted for and adequately explained 94.65 % of the total variation. The existence of quadratic terms shows curvilinear nature of graph.

Effect of rotational speed and feed rate on fennel seed extraction efficiency

The effect of rotational speed and feed rate on extraction efficiency is shown in Fig. 1 to Fig. 3 which shows that as the rotational speed increased, the extraction efficiency increased up to certain maxima and if rotational speed is increased beyond this level, the extraction efficiency was observed to be decreased. Significant effect of rotational speed was observed on extraction efficiency. This might be due to the fact that low rotational speed have less impact on seeds and there was less friction between the drum and the seeds, which being not sufficient resulted in un-extracted seeds and less extraction efficiency. At higher rotational speed, the friction between the seed extraction drum and the seeds was much higher than the required resulted in increased un-extracted seeds and less extraction efficiency.

The extraction efficiency was found to be increased with increase in feed rate up to certain limit in all type of seed extraction drums i.e. stud bolted drum, loop type drum and leather flap drum. Fig. 1 to Fig. 3 shows that as the feed rate increased, the extraction efficiency was found to be increased up to certain level. As the feed rate increased beyond this level, the extraction efficiency was found to be decreased. This might be due to excess raw material above certain limit creates hindrance for rubbing action between drum and the seed. This resulted into less extraction at higher feed rate.

It was observed that the stud bolted drum was found most efficient for yielding higher extraction efficiency with respect to input parameters such as rotational speed and feed rate as compared to the loop type drum and leather flap drum.

Considering the physical properties of seed, flower and stem, stud bolted drum was found better for extraction of fennel seeds from the plants as compared to loop type and leather flap drum.

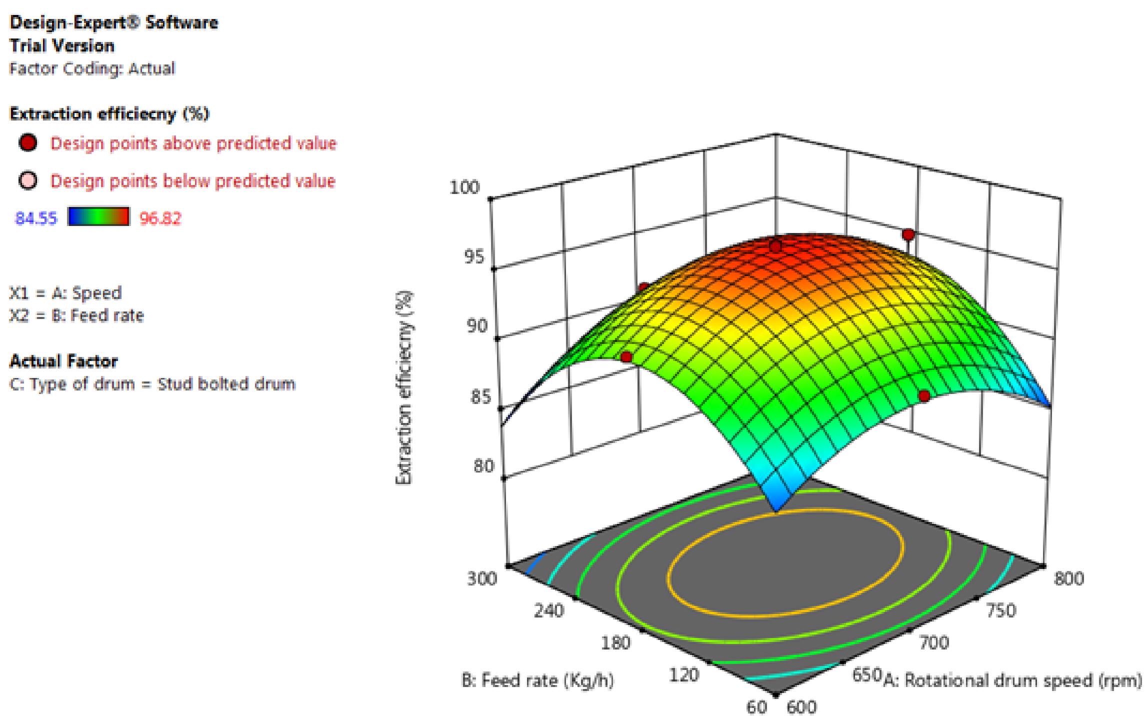

Fig. 1 : Effect of rotational speed and feed rate on fennel seed extraction efficiency (Stud bolted drum)

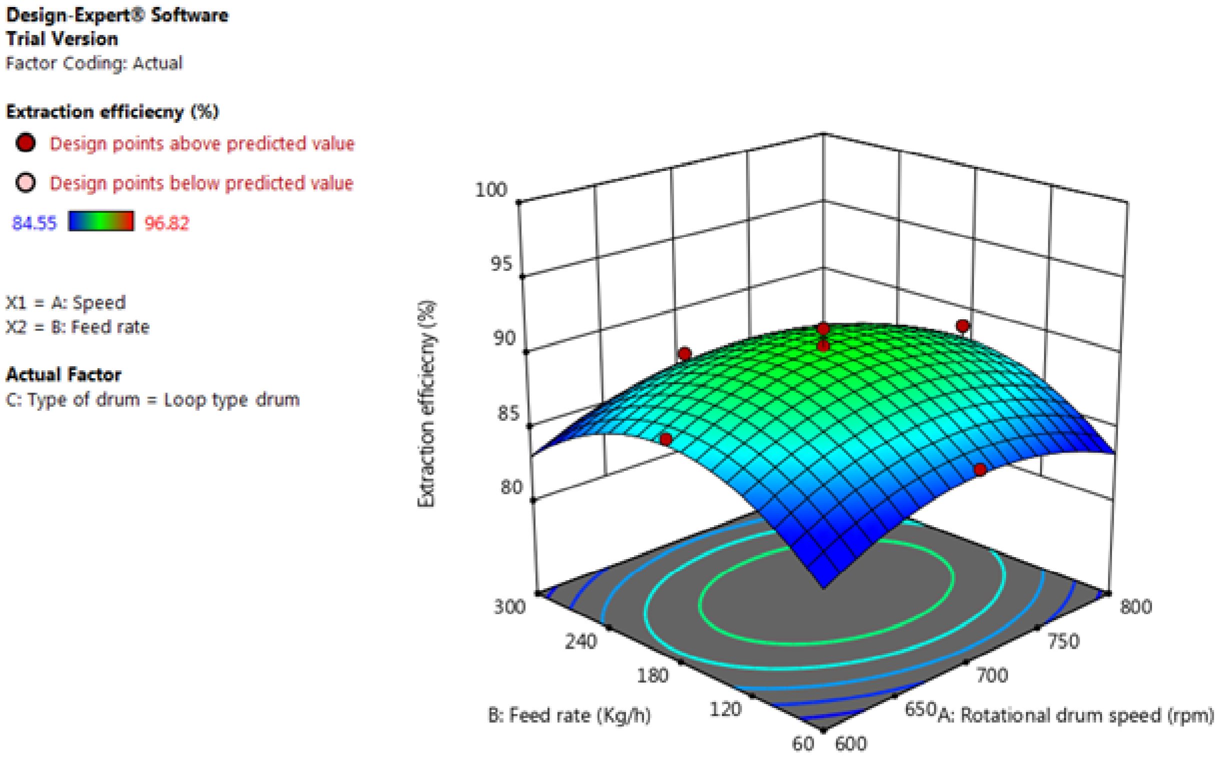

Fig. 2 : Effect of rotational speed and feed rate on fennel seed extraction efficiency (Loop type drum)

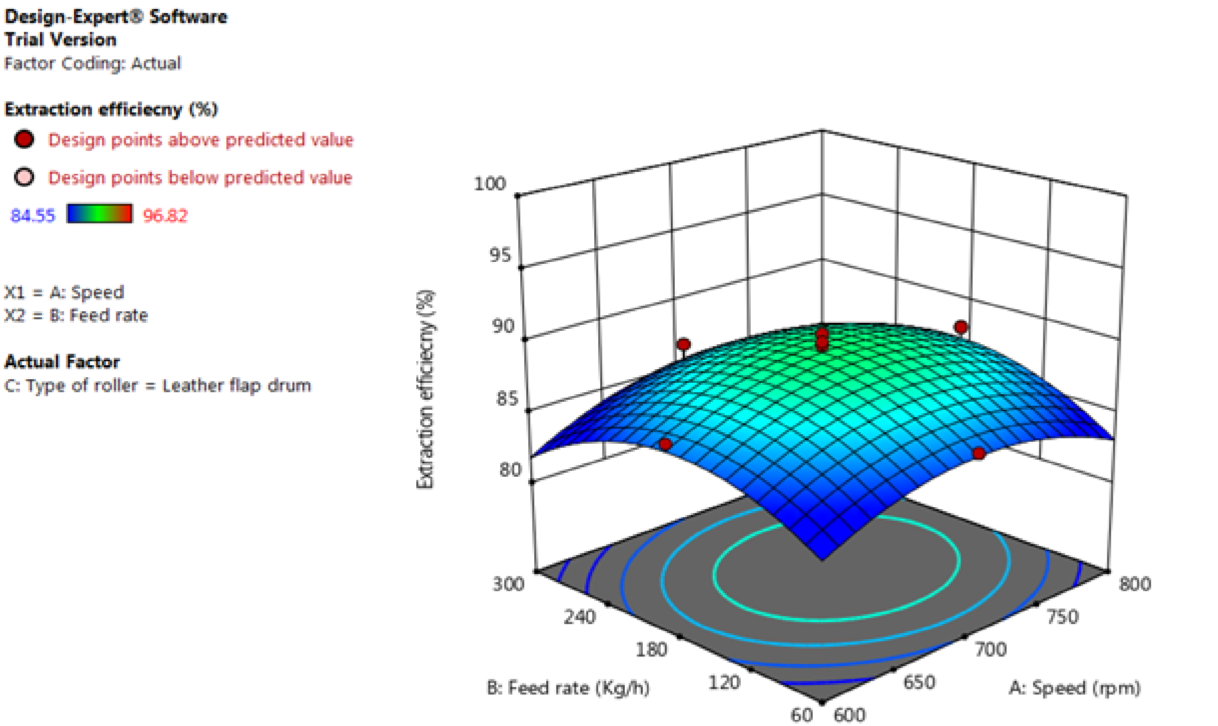

Fig. 3 : Effect of rotational speed and feed rate on fennel seed extraction efficiency (Leather flap drum)

Table 3. Optimized solution generated by the software for fennel seed extraction

Number	Rotational speed, rpm	Feed rate, kg/h	Type of drum	Extraction efficiency, %	Desirability	
1	721.99	186.26	Stud bolted drum	96.49	0.895	Selected

The optimized input parameters for the fennel seed extraction efficiency (Table 3) were found to be: Rotational speed, rpm = 709.22 ~ 700, Feed rate, kg/h = 171.46 ~ 170

Type of drum=stud bolted drum, the predicted fennel seed extraction efficiency=96.50 per cent.

Superimposed contour plots having common superimposed area for all responses are shown in Fig. 4. The superimposed contours of response for rotational speed and feed rate and their intersection zone for maximum seed extraction efficiency indicate range of optimum values of operational parameters as below.

Rotational speed, rpm = 680 -730, Feed rate, kg/h = 160 - 205

Verification of the model for fennel seed extraction

Extraction of fennel seeds (sample size 2 kg) was carried out at optimized input parameters (Rotational drum speed = 709.22~700 rpm, Feed rate = 171.46~170 kg/h) for testing the adequacy of model equations for predicting the extraction response values.

The observed experimental values (mean of three experiments) and values predicted by the equations of the model are presented in Table 4. The experimental values were found to be very close to the predicted values for extraction efficiency. Therefore, it could be concluded from above discussion that model equation 2 is quite adequate to assess the behavior of fennel seed extraction.

Germination

The germination percentage was significantly influenced by the cylinder speed. The highest germination of 91 per cent was observed for fennel seeds at optimized rotational speed and feed rate. The rotational speed affected the germination percentage significantly. It may be due to the fact that higher rotational speed above certain level resulted in higher rubbing forces than the requirement and higher feed rates above certain level at

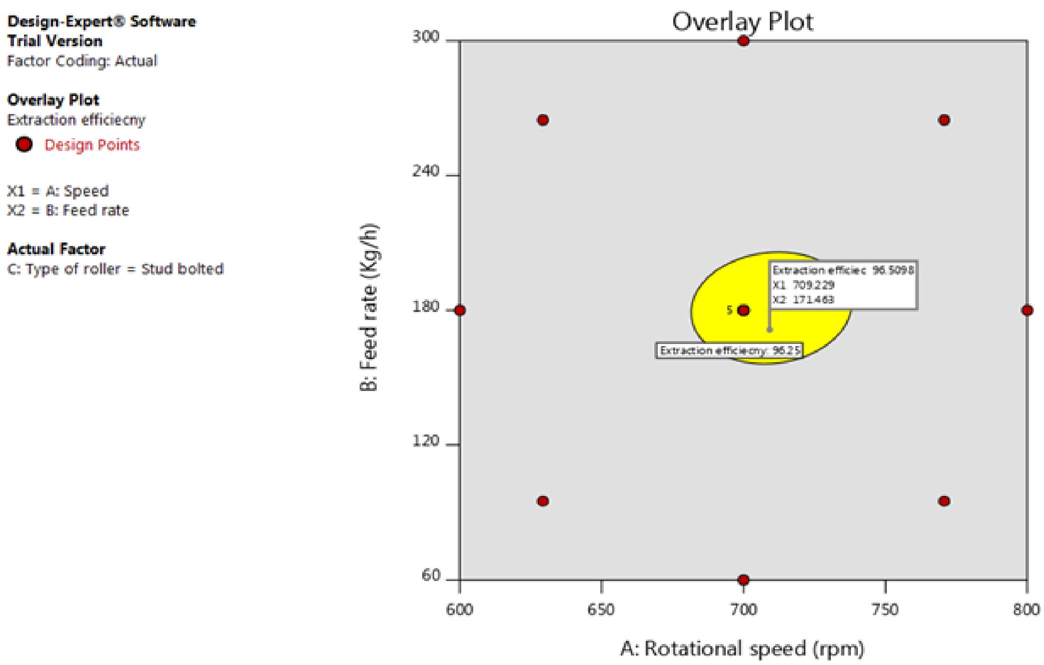

Fig. 4 : Superimposed contour plots for fennel seed extraction

Table 4 Predicted and experimental values of response at optimum process conditions for fennel seed extraction

Response	Predicted value	Experimental value	± SD
Extraction efficiency, %	96.50	97.28*	±1.16

*Average of three replications

fixed concave clearance caused internal seed damage which resulted in decreased germination percentage. The results are in agreement with the researchers Bansal and Lohan (2009).

CONCLUSION

The optimized parameters for fennel seed extraction were found to be stud bolted drum having rotational speed of 700 rpm and feed rate of 170 kg/h. The extraction efficiency was found to be 96.36 per cent at optimized conditions.

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Reaction of Safflower *Carthamus tinctorius* L. Lines Against Aphids *Uroleucon compositae* (Theobald)

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ABSTRACT

The field experiment was conducted at Oilseed Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola in Randomized Block Design during *rabi* 2016-17. In all, thirteen safflower varieties alongwith AI as tolerant and CO-1 as susceptible check replicated thrice were screened for aphid infestation. Foliage drying due to aphids was recorded from each row when plants of CO-1 (Susceptible check) were completely killed. Based on A.I.I., the screening material was categorized in the different aphid reaction. Among the safflower varieties screened against aphids, safflower lines viz;AKS-340, AKS-341, AKS-342, AKS-343, AKS-344, AKS-345, A-1, PBNS 12, PKV Pink, AKS-322, AKS-325 and AKS-326 were found tolerant to aphids recording 1.67, 1.31, 1.33, 1.82, 1.58,1.38,1.54,1.15, 1.87, 1.13 and 2.00 aphid infestation index. AKS-41 and AKS-33 were moderately tolerant, recorded 2.08 and 2.57 aphid infestation index.

Safflower (*Carthamus tinctorius* L.)is an important *rabi* oilseed crop. Safflower oil contains 55-81 *per cent* linoleic acid, 7.42 per cent oleic acid, 1-10 per cent stearic acid and 1-10 per centpalmitic acid with 90 per cent unsaturated and 10 per cent saturated fatty acids. In field several biotic and abiotic factors are responsible for reducing yield of safflower. Insect pest is one of the important biotic factors contributed in reducing yield. Number of insect pests reported in Safflower, of these, aphid (*Uroleucon compositae* Theobald*)* is a serious threat to the safflower production. The infestation of aphid starts from the rosette stage ofthecrop andit attains its peak when the crop is at stem elongation stage. The aphids suck the cell sap from tender parts of the crop with a result the plants fade, dry up thereby causing heavy damage to the crop. Aphid can develop high populations on leaves and terminals ofplants,the pest continuesinfestingthe safflower throughout the crop growth. Both nymphs and adults suck sap from succulent plant parts i.e. foliage and flowers. Moreover, honey dew secreted by the aphids facilitates the occurrence of black sooty mould on foliage which hampers the photosynthetic activity of the plant. An average of 37 per cent loss in seed yield due to aphid was reported.The aphids can be managed by using chemical insecticides. Considering several unintended repercussion of insecticides on agro ecosystem, there is a large scope for developing effective and an ecologically sound pest management approach. Therefore, development of aphid tolerant variety is one of the aspects which can be incorporated in integrated pest management. The insect pest tolerant cultivar is the most suitable minimum cash input for marginal farmers. Hence, through present investigation efforts are being made to study and identify the tolerant sources against aphids.

MATERIAL AND METHODS

The field experiment was conducted at Oilseed Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *rabi* 2016-17. Experiment was laid out in randomized block design with three replications. In all, thirteen varieties along with AI as tolerant and CO-1 as susceptible check were screened. Separate block of susceptible "CO-1" variety as infester block was sown one month before sowing of screening material. Screening material was planted in single row of 2 meter length with 45 cm spacing between rows and 20 cm with in plants. As soon as screening material attained vulnerable stage i.e stem elongation stage, the plants with aphids in infester block were uprooted and shaked over the screening rows to maintain aphid population uniformly. Foliage drying due to aphids was recorded from each row when CO-1 (Susceptible check) was completely killed and categorizedinto 1 - 5 grade (table 1) (Kavitha and Dharma Reddy, 2012).

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Table 1: Foliage drying grade for aphids damage to safflower.

Foliage drying grade (FDG)	% foliage of drying (range)	Visible symptoms
1	0-20 %	Healthy plant with normal capitulum, seed yield equal to protected plant.
2	21-40 %	Healthy plant but yellowing and drying of leaves on main stem and branches, normal capitulum.
3	41-60 %	Drying of 50 *per cent* leaves on tender shoots of the plant, small to medium capitulum with low seed setting.
4	61-80 %	Drying of leaves and tender shoots, withering of branches, stunted growth less number capitulum with very poor seed setting.
5	Above 80%	Death of plant before maturity and no seed yield.

The Aphid Infestation Index (A.I.I.) was calculated by using the formula

$$\text{A.I.I.} = \frac{(1 \times a) + (2 \times b) + (3 \times c) + (4 \times d) + (5 \times e)}{a + b + c + d + e}$$

Where,

1 to 5 = Different foliage drying grades.

a to e = Actual number of plants falling in each of the 5 corresponding foliage drying grades.

On the basis of average aphid infestation index, the safflower lines were categorized into reaction category as suggested by Kavitha and Dharmareddy, 2012.

RESULTS AND DISCUSSION

The safflower aphid tolerant check A-1 and susceptible check Co-1 noted lowest (1.58) and highest (4.94) aphid infestation index expressing tolerant and susceptible reaction, respectively (Table 2).Among the safflower varieties screened against aphids, AKS-340, AKS-341, AKS-342, AKS-343, AKS-344, AKS-345, A-1, PBNS 12, PKV Pink, AKS-322, AKS-325 and AKS-326 were found tolerant to aphids recorded 1.67, 1.31, 1.33, 1.82, 1.58,1.38,1.54,1.15, 1.87, 1.13 and 2.00 aphid infestation index, respectively. The varieties AKS-41 and AKS-33 were found moderately tolerant, recorded 2.08 and 2.57 aphid infestation index, respectively (Table 2). The Present findings are in agreement with the findings of Reddy and Verma(1983)who noticed 117 lines moderately resistant to aphids out of 2457 lines. Similarly, Akashe*et al.* (1993) also reported tolerant lines with character of good yield and having aphid resistance in safflower. Basavangoud*et al.* (1980) and Balikai (2002) reported that,severalsafflower germplasm lines showing stable tolerancereaction to aphids. The aphid tolerant parents GMU 3876, GMU 3924, AKS 322, AKS 325, S-518 and CCC-B2 can be used for development of aphid tolerant varieties.Mane et al. (2012) studied relative tolerance of certain safflower genotypes to aphids, *Uroleuconcompositae*Theobald on the basis of Aphid Infestation Index (AII) and they noticed Co-l entry highly susceptible, recording 86 aphids per 5 cm twig which was associated with dark green leaf colour, thick leaf, soft stem and spiny.

Table 2 : Aphid infestation index and reaction of safflower varieties against aphids

S.N.	Safflower lines	Aphid Infestation Index	Reaction of safflower lines to aphids
1	AKS-340	1.67	Tolerant
2	AKS-341	1.31	Tolerant
3	AKS-342	1.33	Tolerant
4	AKS-343	1.82	Tolerant
5	AKS-344	1.58	Tolerant
6	AKS-345	1.38	Tolerant
7	PBNS 12 (C)	1.54	Tolerant
8	PKV Pink (C)	1.15	Tolerant
9	AKS-322	1.87	Tolerant
10	AKS-325	1.13	Tolerant
11	AKS-326	2.00	Tolerant
12	AKS-41	2.08	Moderately Tolerant
13	AKS-33	2.57	Moderately Tolerant
14	Co-1 (C)	4.94	Highly Susceptible
15	A-1 (C)	1.58	Tolerant

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Seasonal Effect on the Milk Production of Indigenous and Crossbred Cows

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ABSTRACT

The present research work was carried to study the seasonal effect of environmental temperature on milk production of Indigenous and Crossbred cows at Livestock Instructional farm, Department of Animal Husbandry and Dairy Science, Dr. PDKV., Akola with the objectives to study the effect of different seasons on the milk production of indigenous and crossbred cows and to observe the changes in physiological reactions over the season. Meteorological data and milk yield data of indigenous cow and crossbred cow was recorded at University Livestock Instructional Farm and on the basis of interpretation of data the results are concluded. Hot humid climate of rainy season favored the milk production in Indigenous cows, whereas cold humid climate showed increase milk production in Crossbred cows. Increase of humidity showed decrease in milk yield while cold dry climate showed enhanced milk production in crossbred cows in winter season but hot dry winter climate was favorable for milk production of Indigenous cows. Physiological reactions in respect of Indigenous and Crossbred cows exhibited higher pulse rate, lower respiration and higher rectal temperature, during winter season.

There is a close relationship and interaction between the environmental conditions and animal health with their productivity. The environment includes all external conditions and influence the animal health and productivity. The most important component of environment is climate which comprises temperature and humidity. A number of other factors like year and season of calving, length of lactation are known to exert influence on the performance of dairy animal. Seasonal variation in animal performance in tropics is expected to be primarily a manifestation of variation in feed quality and quantity (Forman *et al*., 2008).

Most of the research work is diverted to study the effect of environmental factors in the dairy animal. Considering the effect of global warming in all living beings this study has great importance. Hence present research work was proposed and carried to study the effect of environmental temperature on milk production of Indigenous and Crossbred cows, with major objectives, to study the effect of different seasons on the milk production of crossbred cows and indigenous cows.

MATERIAL AND METHODS

It was a medium term project for three years. Meteorological data for the year 2010-11, 2011-12 and 2012-13 was recorded from the Department of Agronomy. Similarly the milk yield data of indigenous and crossbred cow were also recorded for the period June 2010 to May 2013. During this period the observation on milk yield of indigenous and crossbred cows was recorded. The available meteorological and milk yield data were divided in three seasons namely rainy from June to September, winter from October to January, and summer from February to May, for the year 2010-11, 2011-12 and 2012-13.

The correlation between milk yield and climatic factor i.e. ambient temperature and relative humidity were estimated as per prescribed methods and formulas as suggested by Singh and Choudhary (1977).

RESULTS AND DISCUSSION

The results of three years data are presented in this report.

1. Calving distributions

The month wise distribution of calving of

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indigenous and crossbred cows from June to May during 2010 to 2013 are tabulated in Table 1. It is seen that in all 119 calving consisting 53 calving from indigenous cows and 66 calving from Crossbred Cows took place in different months over a period of three years (2010 to 2013). The trend of calving indicated that maximum calving in range of 13.04 to 28.57 per cent were occurred in Indigenous Cows in the month of August followed by 17.39 to 21.43 per cent in the month of November of each year whereas in case of Crossbred Cows, maximum calving took place between 21.05 to 23.82 per cent in the months of November followed by 7.69 to 26.32 per cent in the month of October. With regards to calving season in cows, it was noticed that maximum calving 39.62 per cent were occurred in rainy season in Indigenous Cows followed by equal number of calving (35.84 per cent) in winter and minimum per cent calving (24.52 per cent) was observed in summer season. On the other and in case of the crossbred highest calving of 59.09 per cent took place in winter in case of crossbred Cows followed by 22.72 and 18.18 per cent in summer and rainy seasons.

Thus, the trend of calving pattern indicated that, winter months were favourable for calving of crossbred cows while rainy season favoured for calving in Indigenous cows. The non-genetic factors particularly nutrition and climate appear to have the influence on calving in cows. Generally, better nutrition is available to cows during rainy and winter seasons compared to summer months which have resulted in maintaining body condition after calving. As a result, reoccurrence of estrus in early summer to have next calving in rainy and winter season. Similarly, the climate of early summer is hot dry which might be the factor to support breeding efficiency in cows. Because, the average maximum temperature during summer was 37.7 to 38.3^0C with RH II humidity levels between 20.09 to 20.94 per cent. Moreover the favourable nutrition during rainy and winter season also favoured the estrus in both the categories of cows thereby resulting a substantial number of calving in summer months. Same trends were also noted by Kulkarni (2011) Ingawale *et al.*(2011) and Pawshe *et al.* (2008) were in agreement to present studies. Who also noted that heat stress affects production and reproduction in high yielding cows.

2. **Correlation studies:** The association between weekly average milk yield and selected meteorological parameters like ambient temperatures and relative humidity in Indigenous and crossbred cows during rainy, winter and summer seasons are shown in Table 2.

Table 1 : Distribution of Calving during 2010-11, 2011-12 & 2012-13

Season	Month	Calving						Per cent Distribution					
		Indigenous			Crossbreed			Indigenous			Crossbreed		
		10-11	11-12	12-13	10-11	11-12	12-13	10-11	11-12	12-13	10-11	11-12	12-13
Rainy	June	00	02	01	00	02	01	0.00	12.50	4.35	0.00	10.53	4.76
	July	02	01	02	03	00	01	14.29	6.25	8.70	11.54	0.00	4.76
	Aug	04	04	03	01	01	00	28.57	25.00	13.04	3.85	5.26	0.00
	Sep.	00	02	00	00	03	00	0.00	12.50	0.00	0.00	15.79	0.00
Winter	Oct	00	02	01	02	05	04	0.00	12.50	4.35	7.69	26.32	19.05
	Nov.	03	03	04	06	04	05	21.43	18.75	17.39	23.08	21.05	23.82
	Dec.	01	01	01	02	04	02	7.14	6.25	4.35	7.69	21.05	9.52
	Jan.	00	01	02	03	00	02	0.00	6.25	8.70	11.54	0.00	9.52
Summer	Feb.	00	00	01	02	00	01	0.00	0.00	4.34	7.69	0.00	4.76
	Mar	00	00	01	03	00	01	0.00	0.00	4.34	11.54	0.00	4.76
	April	03	00	02	02	00	00	21.43	0.00	8.70	7.69	0.00	0.00
	May	01	00	05	02	00	04	7.14	0.00	21.74	7.69	0.00	19.05
Total	**14**	**16**	**23**	**26**	**19**	**21**	**100**	**100**	**100**	**100**	**100**	**100**	

Table 2 : Correlation coefficients of weekly milk production with different climatic factors

Climatic factor	Season											
	Rainy				Winter				Summer			
	2010-11	11-12	2012-13	Pooled	2010-11	2011-12	12-13	Pooled	2010-11	2011-12	2012-13	Pooled
Indigenous Cows												
Ambient Temp.(°C)												
a. Max.	-0.312	0.397	0.538**	0.109	0.112	0.515*	-0.275	0.040	0.916**	0.654**	-0.220	0.368**
b. Min.	-0.136	0.073	0.607**	0.105	-0.118	-0.567**	-0.155	-0.200	-0.892**	-0.539**	-0.416	-0.416*
Relative Humidity (%)												
a. RH I	0.339	-0.310	-0.549**	-0.014	-0.632**	-0.380	-0.451	-0.423**	0.431	0.331	-0.011	0.312*
b. RH II	-0.495*	-0.514	-0.422	-0.113	-0.254	-0.285	-0.262	-0.341*	0.094	0.369	-0.088	0.130
Crossbred cows												
Ambient Temp. (°C)												
a. Max.	-0.264	-0.359	-0.379	-0.168	-0.356	-0.726**	-0.446	-0.104	-0.675**	-0.780**	-0.690**	-0.437**
b. Min.	-0.282	-0.083	-0.554**	-0.162	-0.594*	-0.550**	-0.324	-0.181	-0.762**	-0.859**	-0.861**	-0.507**
Relative Humidity (%)												
a. RH I	0.350	0.357	0.525**	0.276*	-0.682**	0.355	0.376	-0.005	0.048	0.388	0.458	0.434**
b. RH II	0.241	0.430	0.261	0.163	-0.520	0.025	0.319	-0.159	-0.271	0.312	0.235	0.159

* Significant at 5%, ** Significant at 1% level

Table 3. Season wise regression analysis.

	Winter Season	
Co-efficients	**Crossbred Cows**	**Indigenous Cows**
Intercept	18.776	17.721
Minimum Ambient Temperature	(-) 0.119	(-)0.082^{NS}
R^2	0.0328	0.040
	Summer Season	
Co-efficients	Crossbred Cows	Indigenous Cows
Intercept	58.546	45.780
Maximum Ambient Temperature	(-) 0.758**	(-) 0.288*
R^2	0.1126	0.0574

* Significant at 5% ** Significant at 1 %

It is evident from the pooled analysis (Table 2) that, there was a significant impact of maximum and minimum ambient temperatures on weekly milk yield of Indigenous and Crossbred cows during Summer. The significant negative relationship indicated that there was decrease in milk yield of cows with the increase in temperature and vice-versa. The co-efficient values postulated the massage of protecting the Crossbred cows from summer climate as the degree of association was of moderate order (r = -0.437 to -0.507) against low order association (r = -0.368 to -0.416) in indigenous cows. This means the changes in maximum ambient temperatures during summer would reflect on decreasing milk production to the extent of 5.74 per cent in Indigenous cows and by 11.26 per cent in crossbred cows. In other words, with increase in maximum temperature by one degree, there would be decrease in milk yield by 0.288 and 0.758 Kg in Indigenous and crossbred cows respectively (Table 3). In contrast, RH II humidity level did not establish significant association with milk yield in both cow class, indicating humidity levels were dependent on ambient temperature as humidity levels were negatively correlated with temperatures. Thus, hot dry climate was favourable for milk production against hot humid climate.

The ambient temperatures could not show significant influence on milk yield of cows during Rainy season of 2010 to 2013 as the pooled correlation values were found non significant. But, non significantly affected milk yield in positive direction in Indigenous cows and in negative manner in Crossbred cows. This means increase in temperature had a adverse effect on milk yield of Crossbred cows. On the other hand, pooled morning humidity level (RH I) had shown positive significant association with milk yield (r = 0.276) in Crossbred cows. While a non significant negative impact was noticed on Indigenous cows (r = -0.014). The evening humidity levels (RH II) did indicate a positive but non significant influence on milk yield of Crossbred cows. Thus, the trend did postulate that temperature at lower level and higher humidity levels during Rainy season had a adverse effect on milk yield of Crossbred cows.

During winter season, minimum and maximum ambient temperatures exhibited negative non significant association with milk yield in both cow classes on the basis of pooled correlation and regression values indicating that lower temperature or cold climate was favourable for milk production. The pooled association between morning and evening humidity levels with milk yield were negative non significant in Crossbred Cows which means change in humidity levels did not have any appreciable effect on milk yield of cows. In contrast, morning (RH I) and evening (RH II) humidity levels showed negative significant effect on milk yield of Indigenous cows. This means cold climate with lower humidity levels was favourable for milk production in Crossbred cows during winter season. Moreover, the relationship between maximum ambient temperatures and humidity levels were positive non significant (r = 0.149 and 0.191) indicating humidity levels were not influenced by the change in temperature during winter months. Kulkarni(2011) Ingawale *et al.(*2011) and Pawshe *et al*. (2008) Upadhya (2016) also recorded same trends which supports the results of present investigation.

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Impact of various rainwater management systems on productivity, profitability and rainwater use efficiency in saline tract of Purna river valley

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ABSTRACT

The study was conducted on two tier system of rainwater management in saline tract of Purna river valley during 2014-15 to 2017-18 with objectives to increase the productivity, profitability and water use efficiency through suitable double cropping system. In double cropping system of Green gram-Chickpea, the yield of Green gram was found significantly higher (i.e. 5.53 qha^{-1}) under two tier system of rainwater management (contour cultivation with protective irrigation) over the yield recorded in conventional rainwater management systems. Chickpea grown after green gram under two tier system recorded significantly higher yield of 16.77 qha^{-1} in comparison to conventional rainwater management practices. Soybean under two tier system recorded significantly higher yield of 11.52 qha^{-1} as compared with yield recorded in mono tier system (contour and across the slope cultivation) and conventional system of rainwater management. Chickpea yield after harvesting of Soybean was significantly superior over conventional practices of soil moisture management. The significantly higher chickpea equivalent yield of 11.31 qha^{-1} was found in Soybean–Chickpea cropping system as compared with the chickpea equivalent yield of 9.92 qha^{-1} recorded in Green gram–Chickpea cropping system under two tier rainwater management system. The higher net returns of Rs. 58354 per ha was recorded in Green gram-Chickpea cropping system under two tier rainwater management system and the lowest net return of Rs. 7188 was recorded in Soybean–Chickpea cropping system under mono-tier system. Double cropping system of Green gram - Chickpea and Soybean-Chickpea observed statistically at par in B: C ratio.

The Purna valley of Vidarbha region is an East – West elongated basin with slight convexity to the south. The Purna valley of the Vidarbha region covers parts of Amaravati (1738 sq km), Akola (1939 sq km.) and Buldhana (1015 sq km.) districts. This tract spreads on both sides of Purna river , affecting about 892 villages, covering an area about 4.69 lakh ha. Purna river starts from southern slopes of Govilgarh hills of Satpuda range which is the principal drain joining to Tapi river. The major tributaries are Pedhi, Sarapi, Shahanur, Katepurna, Uma, Morna, Man, Mas, Nirguna, Nalganga and Dnyanganga. Locally it is said that there are about 360 tributaries joining Purna river. Of the 4.69 lakh ha area in the affected tract, very little portion is irrigated. Surface irrigation sources are negligible here. The main crops of the saline tract are cotton, sorghum, pigeon pea, black gram and green gram. In the small double cropped pockets wheat, gram and safflower are cultivated.

Rainfed area in Purna river valley are highly diverse ranging from resource rich area with good agricultural potential to resource poor area with much more restricted potential with salinity and sodicity. The soil management in the saline tract of Purna valley is difficult due to the severe erosion rate, swelling, cracking and seizing characteristics. In India over 40% of the agricultural land is located in arid region and the farmers are not even able to recover their investments in agriculture. It has been reported that hardly 35% of the rainwater is used effectively while the remaining 65% goes as runoff, causing severe soil erosion, flooding of rivers and siltation of water bodies. Hence, this valuable asset has turned out to be a liability.

The erosion hazards are greater under cereals and millets crops cultivation. Jat *et al.* (2008) reported that, the black gram was found effective in controlling run off and soil loss as compare to cereals and millet crops. Hence the present investigation was carried out to study the productivity, profitability and water use efficiency through suitable double cropping system (two tier system) in saline tract of Purna river valley in Amravati district of Vidarbha.

MATERIALS AND METHODS

Design

The experiment was carried out in Randomized Block Design with five replications.

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Treatments (Rain Water Management System)

The treatments A) comprised conventional system, control (T_1), B) Mono tier system cultivation across the slope (T_2) and contour cultivation (T_3), C) Two tier system, cultivation across the slope with protective irrigation (T_4) and contour cultivation with protective irrigation (T_5) system of rain water management (RWM). The rainfall received during the experimental years was 571.9 mm, 622.3 mm, 718.1 mm and 427.9 mm, respectively during 2014-15, 2015-16, 2016-17 and 2017-18.

Cropping System and Cultural Practices

The cropping system i.e. Green gram – Chickpea (C_1) and Soybean - Chickpea (C_2) were followed under each rainwater management system. Green gram and Soybean sown during last week of June to first week of July and harvested after 60 to 110 days, respectively during each seasons. Crop varieties Nirmal for Green gram, Jaki-9218 for Chickpea and JS-335 for Soybean were selected. The recommended doses of NPK were applied @ 25:50:20 Kg ha^{-1} to Green gram, 25:50:30 Kg ha^{-1} to Chickpea and 30:75:30 Kg ha^{-1} to Soybean.

Economics and Statistical Analysis

The net returns, benefits cost ratio and production efficiency value in terms of Kg ha^{-1} day^{-1} and Rs. ha^{-1} day^{-1} were calculated with following formulae:

(i) Net Profit = Gross return – cost of cultivation

(ii) $$\text{Benefit: cost ratio} = \frac{\text{Total gross return}}{\text{Total cost of production}}$$

(iii) $$\text{Production Efficiency Value (kg ha}^{-1}\text{ day}^{-1}) = \frac{\text{Chickpea equivalent yield in crop rotation}}{\text{Total duration of crops in that Rotation}}$$

Water Use Efficiency

Water use efficiency was calculated with the help of following formula.

$$\text{Water use efficiency (kg ha}^{-1}\text{ mm)} = \frac{\text{Grain Yield (kg ha}^{-1})}{\text{Total Water applied (mm)}}$$

The individual year's data and pooled data were statistically analysed with the standard methods described by Gomez and Gomez (1984). The results of the study discussed year wise and based on mean value of five years.

RESULTS AND DISCUSSION

Productivity of Cropping System

The pooled data (Table-1) revealed that under the double cropping system of Green gram–Chickpea, Green gram gave significantly higher yield of 5.53 qha^{-1} under two tier system of rainwater management i.e. contour cultivation with protective irrigation followed by across the slope cultivation with protective irrigation (4.59 qha^{-1}) over the yield recorded in mono tier systems of rainwater management. Chickpea grown after green gram under two tier system of rainwater harvesting gave significantly higher yield of 16.77 qha^{-1} in comparison to other moisture management practices. Two tier system of rain water management recorded significantly higher yield of Soybean 11.52 qha^{-1} as compared with yield recorded in mono tier (contour and across the slope cultivation) and conventional system of rain water management. Similarly highest Chickpea yield of 15.52 qha^{-1} was recorded in two tier system of rain water management after harvesting of soybean which was significantly superior over other practices of soil moisture management. The double cropping system of Soybean-Chickpea was found superior followed by Green gram-Chickpea in mono and two tier system of rainwater management. The highest net return of Rs. 58354 per ha was obtained from Green gram-Chickpea cropping system which was highest over to the net returned received from Soybean - Chickpea (Rs. 53539 per ha.) under two tier system of rain water management. Double cropping system of Green gram + Chickpea and Soybean + chickpea observed statistically at par in B: C ratio.

The highest production efficiency (5.67 kg ha^{-1} per day) was observed in Green gram – Chickpea cropping system followed by Soybean - Chickpea(5.52 kg ha^{-1} per day) cropping system under two tier system over mono-tier system of rainwater management. Similarly highest B:C ratio and Water use efficiency was recorded in Green gram-Chickpea cropping system followed by Soybean-

Table: 1 Yield and economics of different cropping system under various system of rain water management (2014-15 to 2017-18)

RWM system		Cropping system	Yield (Qt./ha)										Cost of cultiv-ation,Rs	Gross return, Rs.	Net return, Rs.	B:C
			Kharif					Rabi								
			2014 -15	2015 -16	2016 -17	2017 -18	**pooled Mean**	204 -15	2015 -16	2016 -17	2017 -18	**Pooled Mean**				
Conventional	**Along the slope**	G.gram+ Chickpea	2.31	1.86	2.00	1.50	**1.92**	6.07	5.72	8.50	6.48	**6.69**	27385	34846	7461	1.27
		Soybean+ Chickpea	7.55	5.65	7.00	5.00	**6.30**	5.52	5.24	7.00	5.78	**5.89**	33991	41178	7188	1.21
Mono-Tier	**A/S**	G.gram+ Chickpea	2.82	2.26	2.25	1.75	**2.27**	7.71	7.35	12.50	9.76	**9.33**	28333	45902	17568	1.62
		Soybean+ Chickpea	8.29	6.21	9.37	7.25	**7.78**	5.63	5.36	10.00	7.82	**7.20**	34854	50271	15417	1.44
	contour	G.gram+ Chickpea	4.51	3.62	3.50	3.10	**3.68**	8.59	8.14	15.00	11.85	**10.90**	29019	59612	30593	2.05
		Soybean+ Chickpea	11.25	8.45	10.40	8.40	**9.63**	8.61	8.22	14.50	11.45	**10.70**	35517	68459	32942	1.93
Two-Tier	**PI+A/S**	G.gram+ Chickpea	5.21	4.18	4.40	4.57	**4.59**	11.02	10.46	16.90	13.77	**13.04**	31721	72646	40925	2.29
		Soybean+ Chickpea	12.15	9.11	11.11	9.09	**10.37**	10.07	9.55	15.85	12.95	**12.11**	37058	75815	38757	2.05
	PI+ contour	G.gram+ Chickpea	6.42	5.15	5.49	5.07	**5.53**	11.51	10.93	24.80	19.84	**16.77**	32625	91497	60355	2.79
		Soybean+ Chickpea	14.22	10.65	11.66	9.55	**11.52**	13.12	12.47	20.00	16.50	**15.52**	37958	90980	53539	2.39
	CD @ 5%		1.63	1.18	1.09	0.56	**1.03**	2.10	1.95	1.10	1.17	**2.42**	755.88	7895.25	-	-

Table 2: Production efficiency value under various moisture conservation practices

	Rain water mang.	Cropping system	Gram equivalent yield (kg ha^{-1})	Crop Duration, days	Production efficiency value (kg ha^{-1} day^{-1})
Conventional	**Along the slope**	G.gram+chickpea	345	175	1.97
		Soybean+chickpea	619	205	3.02
Mono tier	**A/S**	G.gram+chickpea	407	175	2.32
		Soybean+chickpea	766	205	3.74
	Contour	G.gram+chickpea	658	175	3.76
		Soybean+chickpea	946	205	4.61
Two tier	**P I+A/S**	G.gram+chickpea	822	175	4.70
		Soybean+chickpea	1019	205	4.97
	P I+contour	G.gram+chickpea	992	175	5.67
		Soybean+chickpea	1131	205	5.52
	CD @ 5%		87.51	-	0.47

Table 3: Water use efficiency (kg/ha^{-1}mm) rainfed cropping system during the year 2014-2018

	RWM	Cropping system	Crop	Mean yield kgha^{-1}	WUE kgha^{-1} mm	% increase over con
Conventional	**Along the slope**	G.gram+chickpea	Ggram	191.75	0.3325	-
			chickpea	669.25	1.1675	-
		Soybean+chickpea	soybean	630	1.0925	-
			chickpea	588.5	1.03	-
Mono tier	**A/s**	G.gram+chickpea	Ggram	227	0.3925	18.05
			chickpea	933	1.6375	40.26
		Soybean+chickpea	soybean	778.25	1.3625	24.71
			chickpea	720.25	1.265	22.82
	Cont.	G.gram+chickpea	Ggram	368.25	0.645	93.98
			chickpea	1089.5	1.9175	64.24
		Soybean+chickpea	soybean	962.5	1.325	21.28
			chickpea	1069.5	1.8825	82.77
Two tier	**PIA/S**	G.gram+chickpea	Ggram	443.75	0.815	145.11
			chickpea	1060	2.295	96.57
		Soybean+chickpea	soybean	987	1.815	66.13
			chickpea	968	2.1325	107.04
	PICont.	G.gram+chickpea	Ggram	546.75	0.9725	192.48
			chickpea	1107.5	2.965	153.96
		Soybean+chickpea	soybean	1154.25	2.0125	84.21
			chickpea	1263.25	2.735	165.53

Chickpea in two tier system over mono-tier system of rainwater management, similarly highest rainwater conservation was observed in contour cultivation followed by across the slope cultivation.

From the result it was observed that the protective irrigation with contour and across the slope cultivation during dry spell in monsoon season and during moisture stress in winter is beneficial over mono-tier system of rain water management.

Economics of cropping system

The economics of Green gram-Chickpea and Soybean-Chickpea were studied and presented in Table 1. The expenditure of Rs. 31,721 ha^{-1} was incurred on the cultivation of Green gram-Chickpea and Rs. 37,058 ha^{-1} was incurred on Soybean–Chickpea cropping system with cultivation across the slope and protective irrigation. While, Green gram-Chickpea cropping system incurred Rs. 32,625 ha^{-1} and in Soybean-Chickpea, it was Rs. 37,958 for contour cultivation with protective irrigation.

The highest Gross returns of Rs. 91,497 and Net return of Rs. 60,355 was obtained from the Green gram – Chickpea in two tier system of rain water management. The lowest Gross returns of Rs. 34,846 with net return of Rs. 7461 was found in the Green gram-Chickpea cropping system with Conventional system of moisture management (i.e. along the slope cultivation).

Production Efficiency

The production efficiency value was worked out on equivalent yield basis and results are given in Table 2. Production efficiency value in terms of kg ha^{-1} day^{-1} was increased with increasing combination of moisture management practices under both the cropping systems. Production efficiency 5.67 kg ha^{-1} day^{-1} was recorded in Green gram-Chickpea cropping system over Soybean–Chickpea (5.52 kg ha^{-1} day^{-1}) cropping system.

B: C ratio

The Green gram –Chickpea followed by Soybean - Chickpea double cropping system were found best for higher production efficiency and net returns under contour cultivation with protective irrigation followed by across the slope cultivation with protective irrigation in deep black soil (Table-1). The Benefit cost ratio of Green gram-Chickpea (1:2.79) and Soybean-Chickpea (1:2.41) double cropping system showed that the management of rain water with contour and across the slope cultivation supported with protective irrigation from pond (two tier system) is economically viable in the deep black soil of Saline tract Purna river valley.

Water Use Efficiency

In two tier system the water use efficiency was recorded 2.01 kg ha^{-1} mm^{-1} in Soybean and 2.735 kg ha^{-1} mm^{-1} in Chickpea under Soybean-Chickpea cropping system in treatment contour cultivation with protective irrigation (Table- 3). The water use efficiency of 2.97 kg ha^{-1} $mm^{-1}$was recorded in Chickpea and 0.97 kg ha^{-1} mm^{-1} was recorded in Green gram in Green gram-Chickpea cropping system. The water use efficiency was recorded in all tested crops under two tier system was higher over other moisture management system.

CONCLUSION

From the results it is concluded that the two tier system i.e. contour and across the slope cultivation with protective irrigation during dry spell in monsoon and moisture stress in rabi is beneficial over mono tier system of rain water management in vertisols of Saline tract.

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Farm Mechanization Knowledge, Attitude and Requirements of Farmers: A Step Towards Enhancing Farmers' Income

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ABSTRACT

The research endeavor was ascertained in the Nagpur district of Maharashtra State. An exploratory research design of social science was used. The two tehsils from the district were selected purposively on the basis of most of the work regarding farm mechanization was underwent due to intervention of Department of Agriculture. Five villages from each tehsil and ten respondents from each village were randomly selected. Total 100 respondents were considered for the research study. The purpose of the study was to analyze the farmer's knowledge towards farm mechanization as well as to assess the farmer's requirement with regard to farm mechanization. The findings with regard to knowledge level of the respondents about improved farm implements and machinery revealed that 53.00 per cent of the respondents had medium level of knowledge followed by 37.00 per cent and 10.00 per cent of the respondents were observed in high and low knowledge level category respectively. The knowledge of respondents about various farm implements and machineries utilized in different farm operations were ascertained and it was found that respondents were familiar with the working of mould board plough, harrow, dibbler, weeder, tractor and bullock cart and it were known to cent per cent respondents. Whereas complete knowledge about power sprayer (88.00%), thresher (87.00%), seed cum fertilizer drill (81.00%), power operated rotavator (80.00%), hand compressed sprayer (78.00%) and mini dal mill (68.00%) were noticed. *Attitude is key determinant in the adoption process of any improved technology*, hence attitude towards farm mechanization was judge with help of teacher made attitude test and the findings revealed that 62.00 per cent of respondents had shown moderately favourable attitude while 22.00 per cent and 13.00 per cent of respondents recorded in highly favourable and less favourable attitude category respectively. Farmer's requirements regarding farm mechanization were access and provision of credit facility (88.00%), provision of subsidies with low interest rate (83%), development of hand (86.00%) & multipurpose farm implements (78.00%) and provision of continuous electric supply at subsidized rate for farm work (75.00%) were some of major requirements quoted by respondents about farm mechanization. To enhance farmers' income by 2022, multi-agency approach needs to be adopted by research and extension in a consistent and planned manner, as the contributions to increase the farm incomes come not only from technological innovations, but also significantly from institutional support, infrastructural facilitation and policy intervention.

Mechanized agriculture is the process which initiates the use of agricultural machinery to mechanize the work of agriculture and to reduce the human efforts and the drudgery. Farm machines have played a paramount role in increasing the agriculture production and have grown to a sizable industry in India. The key to economic development lies in raising agricultural productivity which directly involves the utilization of more energy resources (Jekayinfa, 2006). The continuous increase in wages of labour, unavailability of labours, bullocks, stipulation of time period to perform agricultural operation in lowest span of time, weather conditions, etc., are the factors which makes necessity for use of farm mechanization (Kumar, 2011). Farm mechanization has been helpful to bring about a significant improvement in agricultural productivity. Thus, there is strong need for mechanization in agricultural operation (Starkey, 1998).

Farm mechanization provides the technology to facilitate agricultural growth through efficient utilization of inputs. Adoption of mechanizations ensures timeliness of agricultural operation reduces cost of production as well as reduces drudgery. The farmers with small and marginal land holding can able to utilize the machineries in different operation through the custom hiring. Government of India, as well as Maharashtra Government through their various agencies, schemes promoting the farm mechanization for the socio-economic development of the farming community. As efforts were initiated from

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the governmental agencies to make available the various farm implements and machineries at village level by allocating required funds, subsides etc. through different development programmes for farmers hence the study was carried out with following objectives.

1. To study the knowledge of respondents about improved farm implements and machineries and to evaluate relationship between selected characteristics of respondents and their knowledge towards farm mechanization.
2. To study the attitude of respondents to towards improved farm implements and machineries.
3. To access the requirement of respondents regarding farm mechanization

MATERIAL AND METHODS

The present research study was conducted in Nagpur district of Maharashtra State. Two tehsil i.e. Mouda and Bhivapu from the district were purposively selected as more number of farmers benefitted due to farm mechanization scheme of Department of Agriculture. Five villages from each tehsil; and 10 farmers from each village were randomly selected, which was composed of 100 respondents from the 10 villages under the study. The data were collected with help of a pretested interview schedule from the respondents at their work place or at their homes. The collected data were tabulated and analyzed by applying statistical methods.

RESULT AND DISCUSSION

1. Overall knowledge level of farmers about farm implements and machineries

The awareness of the respondents about improved farm implements and machineries were considered and after due application of the statistical tools the respondents were grouped into three categories. The table shows that majority of the respondents (53.00%) were belonged to medium level of knowledge regarding farm implements and machineries of farm mechanization. It was followed by 37.00 per cent and 10.00 per cent of respondents had high and low level of knowledge about farm mechanization respectively. Slightly over half of the respondents had medium level of knowledge, this could be due to low level of awareness, and unavailability of improved farm implements of farm work. As farm mechanization slowly improving in the area under study, due to intervention of Department of Agriculture, the results of the same will be recognize in the years to come.

Table 1: Distribution of the respondents according to their level of knowledge about improved farm implements and machineries.

S.N.	Knowledge level	Respondents (n=100)	
		Frequency	Percentage
1	Low (Upto 33.33)	10	10.00
2	Medium (33.34 to 66.66)	53	53.00
3	High (Above 66.66)	37	37.00
	Total	**100**	**100.00**
	Mean- 62.93	SD- 17.32	

The findings were in concurrence with the findings reported by Dhere (2012) who reported majority of the respondents (79.00%) in medium level of knowledge.

2. Implement wise knowledge of the respondents about farm mechanization

Knowledge of the respondents refers to awareness about farm implements, machineries utilized in the different farm operations. The awareness of the farmers was ascertained about the farm implements and farm machineries useful in farm mechanization.

The farm implements and machineries were categorized in eight sub heads according to the nature, type and time of work i.e. land preparation, planting and sowing, intercultural operations, plant protection, harvesting and threshing, postharvest implements and machineries utilized for the transportation purpose. The data regarding operation wise knowledge of the respondents about farm implements and machineries were presented in Table no. 2.

A. Land Preparation

It was observed from Table that animal drawn land preparatory implements viz. mould board plough and harrow was know to cent per cent respondents (100.00%) followed by disk plough (75.00%), rotavator (64.00%) and ridger (40.00%) respectively.

Table 2 : Distribution of the respondents according to their implement and farm machineries wise knowledge about farm mechanization.

S. N.	Farm implements and farm machineries	Knowledge of the respondents (n=100)					
		Complete		Partial		Unknown	
		Freq.	%	Freq.	%	Freq.	%
A	**Land preparation- Animal drawn**						
1	Mould board plough	100	100.00	00	00.00	00	00.00
2	Disk plogh	75	75.00	13	13.00	12	12.00
3	Harrow	100	100.00	00	00.00	00	00.00
4	Ridger	40	40.00	32	32.00	28	28.00
5	Rotavator	64	64.00	17	17.00	19	19.00
	Land preparation- Power operated						
6	Rotavator	80	60.00	14	14.00	6	6.00
7	Mould board plough	88	88.00	8	8.00	4	4.00
8	Ridger	60	60.00	10	10.00	30	30.00
9	Furrow opener	60	60.00	20	20.00	20	20.00
B	**Planting and sowing-Manual**						
10	Dibbler	100	100.00	00	00.00	00	00.00
11	Seed cum fertilizer drill	80	80.00	20	20.00	20	20.00
	Planting and sowing-Animal drawn						
12	Seed cum fertilizer drill	81	81.00	9	9.00	10	10.00
13	Seed drill over plough	66	66.00	24	24.00	10	10.00
14	Rice planter	45	45.00	40	40.00	15	15.00
15	Sugarcane planter	30	30.00	40	40.00	30	30.00
C	**Intercultural operation- Manual**						
16	Weeder /Hoe	95	95.00	5	5.00	0	0.00
	Intercultural operation- Power operated						
17	Power weeder	55	55.00	40	40.00	5	5.00
18	Grass weed splashier	35	35.00	25	25.00	40	40.00
D	**Plant protection equipment-Manual**						
19	Hand compressed sprayer	78	78.00	12	12.00	10	10.00
20	Knapsack sprayer	67	67.00	25	25.00	8	8.00
21	Foot sprayer	45	45.00	25	25.00	30	30.00
E	**Plant protection equipment- Power operated**						
22	Tractor operated sprayer	40	40.00	38	38.00	22	22.00
23	Power sprayer	88	88.00	12	12.00	00	00.00
E	**Harvesting & threshing- Power operated**						
21	Groundnut pod striper	30	30.00	22	22.00	48	48.00
22	Chaff cutter	55	55.00	37	37.00	8	8.00
23	Thresher	87	87.00	13	13.00	00	00.00
F	**Post-harvest equipment's**						
24	Mini rice mill	60	60.00	35	35.00	5	5.00
25	Mini dal mill	68	68.00	22	22.00	10	10.00
26	Extractor	5	5.00	20	20.00	75	75.00
27	Grinder/Pulveriser/Polisher	24	24.00	36	36.0	40	40.00
G	**Transportation**						
28	Bullock cart	100	100.00	00	00.00	00	00.00
29	Tractor trolley	100	100.00	00	00.00	00	00.00

In case of power operated machineries majority of the respondents had complete knowledge about mould board plough (88.00%) followed by rotavator (88.00%) and equal per cent of the respondents i.e. 60.00 per cent had well aware about ridger and furrow opener.

B. Planting and sowing

The cent per cent respondents had complete knowledge about the manual tools dibbler, followed by seed cum fertilizer drill (88.00%). With regard to animal drawn farm implements used for planting and sowing operation 81.00 per cent of the respondents had complete knowledge about seed cum fertilizer drill which was followed by seed drill over plough (66.00%), rice planter (45.00%) and sugarcane planter (30.00%) was known to the respondents. It was found that majority of the respondents had knowledge about dibbler, seed cum fertilizer drill and seed drill over plough.

C. Intercultural operation

Respondents knowledge with regard to the farm implements utilized for intercultural operation were tested and it was found that majority of the respondents (95.0%) had complete knowledge about the manual weeder/hoe. It was worth to note here that 5.00 per cent of the respondents were found in partial knowledge category about manual weeder.

In case of power operated farm machineries utilized in intercultural operation, the 55.00 per cent and 35.00 per cent of the respondents had complete knowledge about power weeder and grass weed splashier respectively, whereas 40.00 per cent of the respondents had unaware about grass weed splashier (40.00%).

D. Plant protection equipment

The knowledge level of the respondents were judge toward farm implements used for plant protection and it was found that 78.00 per cent hand 67.00 per cent of the respondents had complete knowledge about hand compressed sprayer and knapsack sprayer respectively. In case of power operated plant protection equipment 88.00 per cent of respondents were found in complete knowledge category toward use of power sprayer while 40.00 per cent known about tractor operated sprayer.

E. Harvesting and threshing equipment

Majority of the respondents 87.00 per cent well aware about thresher utilized for harvesting while 55.00 and 30.00 per cent reported knowledge about chaff cutter and groundnut pod striper. It was also worth to note that 48.00 per cent of the respondents had no knowledge about ground nut pod striper.

F. Post-harvest implements

As far as the knowledge of the respondents about the post-harvest implements 68.00 per cent of the respondents had complete knowledge about mini dal mill followed by mini rice mill (60.00%) and gridnder/purvariser (24.00%). It was also observed that 75.00 per cent of the respondents had no knowledge about extractor followed by 36.00 and 35.00 per cent of the respondents were not aware about grinder and mini rice mill respectively.

G. Transportation

Transportation means like bullock cart and tractor trolley were well known to cent per cent of the respondents.

3. Relationship between selected characteristics with knowledge of farmers about farm mechanization

Efforts were made to work out the relationship of various characteristics of respondents with their knowledge about farm mechanization.

Table 3. Relationship between selected characteristics of respondents with their knowledge about farm mechanization.

S.N.	Characteristics	'r' value
1	Age	-0.01884 NS
2	Education	0.3303**
3	Size of family	0.3253**
4	Land holding	0.5032**
5	Annual income	0.3366**
6	Sources of irrigation	0.1101 NS
7	Extension contacts	0.2579**
8	Source of information	0.3836**
9	Innovativeness	0.3442**
10	Risk preference	0.3760**

The perusal of the data displayed in Table 3 clearly indicates that, selected characteristics of the respondent's viz. education, size of family, land holding, annual income, extension contacts, sources of information, innovativeness and risk preference had positive and highly significant relationship at 0.01 per cent level of probability with knowledge about farm mechanization.

Whereas, the characteristics of respondents namely age and source of irrigation were non-significantly related with knowledge. It is important to quote that with increase in level of education, annual income, extension contact, sources of information and innovativeness increases in farmers' knowledge towards farm mechanization.

4. Attitude of farmers about farm implements and machineries

Attitude of an individual is an important aspect in process of technology adoption. Hence the attitude of the farmers towards farm mechanization were accessed with help of teacher made attitude test. The findings of the study revealed that 65.00 per cent of respondents were noticed with moderately favourable attitude while 22.00 per cent and 13.00 per cent of respondents were found in highly favourable and less favourable attitude category respectively towards farm mechanization.

Table 4: Distribution of the respondents according to their attitude about improved farm implements and machineries.

S.N.	Attitude level	Respondents (n=100)	
		Frequency	Percentage
1	Less favourable	13	13.00
2	Moderately favourable	65	65.00
3	Highly favourable	22	22.00
	Total	**100**	**100.00**

5. Requirement of the respondents regarding farm mechanization

The suggestion from the respondents were assessed to know about the requirements of the respondents about farm tools, implements and farm machineries. The requirement quoted by the farmers were presented in Table no. 5.

It was concluded from Table 5 that, majority of the respondents (88.00%) suggested that provision should be made for the credit facility for purchase of farm machineries, followed by the need to development of handy farm implements (86.00%).The 84.00 per cent of the respondents necessitated the simple technique for the

Table 5 : Distribution of respondents according to their requirement regarding farm mechanization

S. N.	Requirement of the respondents	Respondents (n=100)	
		Ferq.	Percentage
1	Provision of credit facility to purchase farm implements and machineries	88	88.00
2	Reduction in drudgery by developing suitable handy implements	86	86.00
3	The implements and machineries may have simple technique to use.	84	84.00
4	Provision of subsidies and high credit availability at low interest rate for purchase of tractor	83	83.00
5	Establishment of agricultural product processing unit on village basis	83	83.00
6	Facilitating the group of farmers to own the high cost machineries by providing financial support	81	81.00
7	Development of multipurpose implements and machineries	78	78.00
8	Provision of uninterrupted electric supply	75	75.00
9	Development of equipment and machineries bank at village level	71	71.00

farm machineries followed by provision of subsidies and minimum interest rate for buying of farm tillers (83.00%), processing unit at nearby places (83.00%), financial support for the cooperative farmers group for farm machineries (81.00) while 78.00 per cent of the respondents reported the need to develop multipurpose farm implements. The most important factor is the provision of uninterrupted electric supply required for the farm machineries was mentioned by 75.00 per cent of the respondents. Their is need to develop the farm implement and machineries bank at village level by contribution of farmers and institution was reported by 71.00 per cent of the respondents.

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RESEARCH NOTES

Effect of Plant Geometry and Sowing Dates on Growth and Yield of Semi-Rabi Pigeonpea

Pigeonpea plant is known to provide several benefits to soil such as fixing atmospheric nitrogen, adding organic matter and micro nutrients, and breaking hard pan with its long tap roots and, thereby sometimes referred as "biological plough". Among pulses, pigeonpea [*Cajanus cajan* (L.) Millsp.] is the most important *kharif* season crop in India. This crop is grown for multipurpose uses as a source of food, feed, fuel and fertilizer. Pigeonpea is nutritionally high in protein (19 - 22%) crop with high digestible protein (68%), low in fat and sodium with no cholesterol and has high dietary fiber, vitamins (thiamine, riboflavin, niacin and choline) and minerals (iron, iodine, calcium, phosphorous, sulphur, and potassium). It is commonly known as redgram or arhar and grows in *kharif* as well as semi-rabi season where *kharif* crop could not be sown due to late onset of monsoon or crop damage due towater logging or due to flood inriver bank fields. To increase yield and improve quality of pigeonpea, it is necessary to use proper planting geometry with combination of phosphate management. It also helps for economic use of resources and maximization of profit. In case of pigeonpea protein quality, B: C ratio and yield were highest at 45 cm row spacing with 50 kg P_2O_5/ha. Considering the above fact, attempt was made to study the effect of planting geometry on semi-*rabi*pigeonpea.

An experiment was carried out during semi-rabi season of 2015-16 at Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The experiment was laid out in split plot design in three replications with 16 treatment combinations i.e. four main plot treatments (spacing) viz., S_1 (45 cm x 20 cm), S_2 (45 cm x 20 cm), S_3 (60 cm x 20 cm) and S_4 (60 cm x 20 cm) and four sub-plot treatments (sowing dates) viz., S_1 (30 July, 31 MW), S_2 (15 Aug, 33 MW), S_3 (30 Aug, 35 MW), and S_4 (15 Sept, 37 MW). Gross plot size for experiment was 5.4 m x 4.0 m. The experimental site was Vertisol, clayey in texture, low in

Table 1: Effect of different treatments on growth parameters and yield of pigeonpea.

Treatment		Seed yield (kg/ha)	Plant height (cm)	Branches plant^{-1}	Seed weight plant^{-1}(g)	50% flowering	100-seed weight (g)
A. Main Plot (Planting geometry)							
1	30 July (31 MW)	1724	115.03	7.42	23.73	105.00	9.35
2	15 Aug (33 MW)	1635	98.16	7.11	22.38	105.58	9.24
3	30 Aug (35 MW)	1576	92.66	6.87	21.22	106.25	9.17
4	15 Sept (37 MW)	1471	61.02	6.13	19.86	106.67	9.12
	S.Em$\pm$	13.91	2.01	0.07	0.27	0.88	0.025
	CD at 5%	49.05	7.10	0.25	0.94	NS	0.090
B. Sub plot (Sowing dates)							
1	45 cm x 20 cm	1819	98.58	6.43	20.37	107.67	9.10
2	60 cm x 20 cm	1720	92.37	6.62	22.67	106.50	9.19
3	75 cm x 20 cm	1541	90.02	7.00	24.42	105.33	9.14
4	90 cm x 20 cm	1427	85.90	7.47	26.03	104.00	9.45
	S.Em$\pm$	39.87	1.93	0.06	0.39	0.65	0.022
	CD at 5%	117.06	5.68	0.18	1.15	NS	0.064

nitrogen content, medium in phosphorus and rich in potash. Soil reaction was found to be slightly alkaline. The pigeonpea variety ICPL 87119 (Asha) was used in experimentation.

The seed yield of sole pigeonpea was influenced significantly with varying plant geometry. The seed yield decreased with increasing plant geometry. The highest seed yield of pigeonpea was recorded with closer spacing of 45 cm x 20 cm over wider spacing of 60 cm x 20 cm spacing of 75 cm x 20 cm and 90 cm x 20 cm. The seed yield influenced due to different plant geometry was found at par with each other. Different date of sowing influenced the seed yield significantly; however, the advancement in sowing dates reduces the grain yield. The similar trend was observed with respect to ancillary parameters. The plant height of sole pigeonpea was highest at 45 cm x 20 cm row spacing and gradually decreased up to 90 cm x 20 cm. However, the number of branches was highest with wider spacing at 90 cm x 20 cm than closer row spacing of 45 cm x 20 cm and 75 cm x 20 cm. On the contrary the seed weight per plant was higher at closer spacing and decreased consequently with wider spacing. The test weight did not influenced significantly with plant spacing's. Various spacing treatments did not differ significantly in respect of days to 50% flowering. The results are in conformity with Sathe and Patil (2012).Interaction effect of planting geometry and date of sowing was found to be non-significant.

The highest seed yield was recorded with plant geometry of 45 cm x 20 cm and / or 60 cm x 20 cm across the date of sowing.

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Performance of Different Greengram Genotypes in Intercropping with Pigeonpea

Maharashtra has a major area of pigeonpea (medium duration) under rainfed condition. It is grown largely as intercropped with short duration crops. Intercropping is an age-old practice being followed by subsistence farmers to achieve their domestic needs. The main advantage of the intercropping is that the component crops are able to use the growth resources more efficiently (Willey, 1979).The initial growth of pigeonpea is very slow and the accompanying intercrops enjoy unrestricted growth, and experience almost no competition from pigeonpea during the first two months. By the time, the intercrop is ready for harvest in October-November, the pigeonpea crop gets well established with the roots penetrating deep down into the soil profile. It provide full opportunity for the long duration pigeonpea crop to grow during the next four to five months making more comprehensive use of land than by any alternate cropping system under rain fed condition. Greengram (*Vigna radiate* L.) is also an important *kharif*pulse crop of India. It is an excellent source of high quality protein. As short duration crop it fit well in various multiple and intercropping systems (Pujari and Sheelvantar, 2002).

The experiment was conducted at the Pulses Research Unit, Dr.PanjabraoDeshmukhKrishiVidyapeeth, Akoladuring *kharif*2011. The experiment was laid out in randomized block design with pigeonpeaassole and in intercrop with greengram(1:2). Sowing of pigeonpeacv. PKV TARA and greengram different genotypes was done on 4th Julyin 45 cm apart rows.The soil of the experimental unit was clayey and the soil pH was 8.04, while the EC nitrogen content, medium in phosphorus and rich in potash. Soil reaction was found to be slightly alkaline. The pigeonpea variety ICPL 87119 (Asha) was used in experimentation.

The seed yield of sole pigeonpea was influenced significantly with varying plant geometry. The seed yield decreased with increasing plant geometry. The highest seed yield of pigeonpea was recorded with closer spacing of 45 cm x 20 cm over wider spacing of 60 cm x 20 cm spacing of 75 cm x 20 cm and 90 cm x 20 cm. The seed yield influenced due to different plant geometry was found at par with each other. Different date of sowing influenced the seed yield significantly; however, the advancement in sowing dates reduces the grain yield. The similar trend was observed with respect to ancillary parameters. The plant height of sole pigeonpea was highest at 45 cm x 20 cm row spacing and gradually decreased up to 90 cm x 20 cm. However, the number of branches was highest with wider spacing at 90 cm x 20 cm than closer row spacing of 45 cm x 20 cm and 75 cm x 20 cm. On the contrary the seed weight per plant was higher at closer spacing and decreased consequently with wider spacing. The test weight did not influenced significantly with plant spacing's. Various spacing treatments did not differ significantly in respect of days to 50% flowering. The results are in conformity with Sathe and Patil (2012).Interaction effect of planting geometry and date of sowing was found to be non-significant.

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Table 1: Effect of greengramgenotypes in pigeonpea intercropping ongreengram equivalent yield.

Treatment	Grain yield (kg ha^{-1})		Greengram equivalent yield(kg ha^{-1})
	Greengram	Pigeonpea	
Pigeonpea+AKM 9911	982	1037	2066
Pigeonpea+PKVM 8802	807	1274	1718
Pigeonpea+PKV AKM-4	1154	1011	2116
Pigeonpea+AKM 9907	849	1089	1878
Pigeonpea+AKM 9-2	606	1007	1717
Pigeonpea+AKM 603	614	1055	1769
Pigeonpea+AKM7-204	650	1001	1850
Pigeonpea+AKM 9-1	604	1018	1765
S.Em±	23.3	57.3	59.5
CD 5%	70..8	174	180.5
CV%	5.16	8.32	5.5

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was 0.44 dSm^{-1}. The organic carbon of the soil was 0.46 per cent during the years of study. The soils of the experiential field was low in available nitrogen (236 kg/ha), medium in available phosphorus (18.80 kg/ha) and high in available potassium (363 kg/ha).A uniform dose of 25 and 50 kg ha^{-1} of Nand P_20_5 of pigeonpea, was used in all the treatments excluding absolute control. Whole quantity ofNand P in the form of ureaanddi-ammonium phosphate was side drilled just after sowing. All other cultural practices were kept normal and uniform for all the treatments.

Among greengram genotypes significantly higher grain yield of greengram and its equivalent yield were recorded by AKM-4 in intercropping withpigeonpea (2:1)closely followed by AKM 9911 over remaining greengramgenotypes might be due to synergistic effect of component crop. Similar result was obtained by Rathod*et al.*, 2004 and Kumar *et al.*, 2012. However, pigeonpea yield was highest when intercropped with greengram genotypes AKM-8802 followed by AKM-9907.

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Kawarkhe, V.J., R.N. Jane and Manisha Deshmukh, 2003.Effect of nitrogen and specing levels on growth and flower yield of China Aster, PKV Res. J., 27 (2) : 163-165.

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