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Effect of weather variability, plant density and fertilizer regimes on productivity and uptake of nutrients by cotton cv. AKH 081 under rainfed condition of Vidarbha region of Maharashtra

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Abstract
A field experiment was conducted during *kharif* seasons of 2013-14 and 2014-15 at Research farm of AICRP for Dryland Agriculture, Dr. PDKV, Akola to optimize the plant density and fertilizer regimes for yield maximization under weather variability and nutrient uptake by cotton crop under rainfed condition. The experiment was laid out in split plot design with eighteen treatment combinations in three replications. The soil of experiment was medium black (*Inceptisols*) clayey in texture, slightly alkaline in reaction, low in organic carbon, available nitrogen and available phosphorus whereas high in available potassium. The pooled results indicated that seed cotton and stalk yield was significantly higher in monsoon sowing, 200% plant density and in 200% RDF. The interaction of monsoon sowing and 200% plant density was significantly higher in respect of seed cotton and stalk yield during 2014-15. The N, P and K uptake was found significantly higher in monsoon sowing, 200% plant density (2.22 lakh ha^{-1}) and in 200% RDF (120:60:60 NPK kg ha^{-1}).

Keywords: Fertilizer regimes, nutrient uptake, plant density, seed cotton yield

Introduction
In Vidarbha region of Maharashtra, cotton is grown predominantly as a rainfed crop. As such in Vidarbha region about 87 per cent cultivable land is under rainfed farming. Weather plays an important role in rainfed agricultural production. Agronomic strategies to cope with changing weather are available but not fully explored, and have more emphasis in view of the happening issue of climate change impacts reportedly inducing regional variability and uncertainty of rainfall affecting agricultural production. As such management of rainfed cotton production system is challenging and is a high-risk enterprise given the uncertainty of rainfall in its onset and distribution during the growing season. In fact monsoon onset behaviour has direct bearing on the acreage of cotton crop as timely onset with significant amount of sowing rains favours timely sowing of the crop within the normal sowing window. As often observed in recent years, late monsoon onset and/or non-receipt of significant pre-soaking rains pushes cotton crop beyond its normal sowing window (June 30) and cotton growers face a problem of low cotton yield in late planting. This has also resulted in decline in cotton sowing and its stagnating rate of growth. In order to cope with the decline in cotton sowing and its stagnating rate of growth, the strategy is to increase production per unit area rather than increase the absolute area of cotton production.

In many countries, narrow row plantings have been adopted after showing improvement in cotton productivity (Ali *et al.*, 2010) [1]. Fertilizer management along with high density planting is important because fertilizer requirement is most likely to be higher under HDP (Jost and Cothren, 2000) [13]. Hence, within the varying rainfed environment, the potential effects of adopting higher plant population with compatible NPK fertilizer management (as fertilizer requirement is most likely to be higher under HDP) offer a good opportunity to boost the crop output. The aim of the experiment was to study the productivity and nutrient uptake by *hirsutum* cotton under weather variability, plant density and fertilizer regimes under rainfed condition of Vidarbha region of Maharashtra.

Materials and Methods

The experiment was carried out at Research farm of All India Coordinated Research Project for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola Maharashtra during *kharif* seasons of 2013-14 and 2014-15. The soil of experimental site was medium black (*Inceptisols*), clayey in texture, slightly alkaline in reaction (pH 8.1), low in organic carbon (0.54%), low in available nitrogen (187.3 kg ha^{-1})and available phosphorus (14.8 kg ha^{-1}) whereas high in available potassium (316.0 kg ha^{-1}). The experiment was laid out in split plot design with eighteen treatment combinations in three replications. The treatments included weather variability in factor A (two sowing dates S_1- monsoon sowing and S_2- late sowing) and plant density in factor B (P_1- 60 cm x 30 cm, 1.11 lakh, P_2- 60cm x 10 cm, 1.66 lakh and P_3- 45 cm x 10cm, 2.22 lakh) in main plots treatment with three fertilizer regimes in factor C (F_1-100% RDF, 60:30:30, F_2-150% RDF, 90:45:45, and F_3-200% RDF, 120:60:60 NPK kg ha^{-1}) were in sub plot treatments. The N, P and K were applied through Urea, single super phosphate and muriate of potash respectively. Half N, full P and full K was applied at the time of sowing and half N at 30 DAE. Cotton crop variety was AKH 081. Plant samples were analyzed for uptake of nitrogen, phosphorus and potassium as per standard methods. Rainfall during the *kharif* seasons was 821.7mm and 570.1mm during 2013-14 and 2014-15 seasons respectively as against normal rainfall of 688.0 mm.

Results and Discussion

Seed cotton yield

The data on seed cotton yield as influenced by the different treatments are presented in Table 1. Mean seed cotton yield was 1657 kg and 1215 kg ha^{-1} during 2013-14 and 2014-15 seasons and 1436 kg ha^{-1} in pooled analysis. Comparatively higher seed cotton yield in 2013-14 might be due to extended crop duration.

Weather variability in general created through different sowing time significantly influenced the seed cotton yield. Significantly higher seed cotton yield (1846 and 1359 kg ha^{-1}) was obtained with monsoon sowing and it was significantly decreased in late sowing (1467 and 1071kg ha^{-1}) during 2013-14 and 2014-15 respectively. In pooled data with similar statistical trend, seed cotton yield was observed 1602 and 1269 kg ha^{-1} in monsoon and late sowing, respectively. Reduction in yield due to delay in sowing was to the extent of 20.5 %, 21.2% and 20.8% respectively during 2013-14, 2014-15 and in pooled.

Table 1: Seed cotton yield and stalk yield as influenced by the weather variability, plant density and fertilizer regime

Treatment	Seed cotton yield (kg ha^{-1})			Stalk yield (kg ha^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Main plot treatment						
A) Weather variability						
S_1- Monsoon sowing	1846	1359	1602	4096	2933	3514
S_2- Late sowing	1467	1071	1269	3445	2390	2917
SE(m)±	32	19	22	106	44	66
CD (P=0.05)	101	61	68	335	139	207
B) Plant density						
P_1- 60 X 15 cm (1.11 lakh plants ha^{-1})	1328	1041	1185	2818	1948	2383
P_2- 60 X 10 cm (1.66 lakh plants ha^{-1})	1682	1195	1439	3819	2847	3333
P_3- 45X 10 cm (2.22 lakh plants ha^{-1})	1959	1409	1684	4674	3190	3932
SE(m)±	39	24	26	130	54	81
CD (P=0.05)	124	75	83	410	170	254
Sub plot treatment						
Fertilizer regime						
F_1- RDF (60:30:30 NPK kg ha^{-1})	1516	1075	1296	3452	2362	2907
F_2-150%RDF(90:45:45 NPK kg ha^{-1})	1678	1230	1454	3789	2668	3229
F_3-200%RDF(120:60:60 NPK kg ha^{-1})	1775	1340	1558	4070	2955	3512
SE(m)±	38	17	21	79	59	54
CD (P=0.05)	112	49	61	231	172	159
Interaction						
S X P						
SE(m)±	56	34	37	184	76	114
CD (P=0.05)	NS	106	NS	NS	240	NS
SX F						
SE(m)±	54	24	29	112	84	77
CD (P=0.05)	NS	NS	NS	NS	NS	NS
P X F						
SE(m)±	66	29	36	137	102	94
CD (P=0.05)	NS	NS	NS	NS	NS	NS
SX P X F						
SE(m)±	94	41	51	194	145	133
CD (P=0.05)	NS	NS	NS	NS	NS	NS
GM	1657	1215	1436	3770	2662	3216

Performance of growth parameters plays an important role in deciding dry matter production and final yield of crop. In the present study, mean values were higher as regards growth and yield parameters under monsoon sowing. Reduction of yield in late sowing was also due to shortening of total crop duration which affected reproductive process of the crop adversely. Higher retention of bolls in early sown crop and shedding of floral structure in late sown crop might have also affected the seed cotton yield. By and large, decrease in yield under late sowing was due to significant decrease in growth attributes, number of bolls harvested plant^{-1}, boll weight and seed cotton yield plant^{-1}. This is in conformity with the findings of Hallikaeri *et al*. (2009) [8], Kumar *et al*. (2014) [15], Ban *et al*. (2015) [2], Dalvi *et al.* (2015) [5] and Pinky *et al.* (2016) [20].

Population density of 2.22 lakh plants ha^{-1} (45 X 10 cm) produced significantly highest seed cotton yield over population of 1.66 lakh plants ha^{-1} (60 X 10 cm) and 1.11 lakh plants ha^{-1} (60 X 15 cm). Least seed cotton yield was recorded in 60 X 15 cm (1.11 lakh plants ha^{-1}). Similar results were observed during both the years of experimentation and in pooled analysis.

High density planting had helped to produce higher biomass at all the growth stages because of optimal light penetration and uptake of major nutrients which favored for increased photosynthetic efficiency. Higher plant density treatment P_3(2.22 lakh plants ha^{-1}) though had smaller individual boll mass (weight) and fewer bolls plants^{-1}, however, the increased number of plants compensated for fewer boll number and smaller boll size and cumulatively yield output was higher under high population density. These results are in agreement with reports of Vories and Glover (2006) [21], Bhalerao *et al*. (2012) [3], Paslawar *et al*. (2015) [19], and Sankaranarayanan *et al*. (2018) [21].

Seed cotton yield was significantly influenced by varying fertilizer regimes. Fertilizer regime of 120:60: 60 NPK kg ha^{-1} was significantly superior over 60:30:30 NPK kg ha^{-1} and on par with 90:45:45 NPK kg ha^{-1} during 2013-14. During 2014-15, fertilizer regime of 120:60:60 NPK kg ha^{-1} recorded significantly higher seed cotton yield as compared to both lower fertilizer regimes (90:45:45 NPK kg ha^{-1} and 60:30:30 NPK kg ha^{-1}). Similar trend as of 2014-15 prevailed in pooled analysis also. The increase in seed cotton yield was to the extent of 10.7% and 17.1% during 2013-14 and 14.4% and 24.6% in 2014 with increase in fertilizer regimes to 90:45:45 NPK kg ha^{-1} and 120:60: 60 NPK kg ha^{-1}, respectively compared to the lowest fertilizer regime of 60:30:30 NPK kg ha^{-1}.In pooled data, corresponding increase in seed cotton yield was to the extent of 12.2 and 20.2% with increase in fertilizer regimes.

Significant increase in seed cotton yield with increase in fertilizer regime was the result of associated increase in various growth and yield attributing characters *viz*. plant height, number of monopodia and sympodia branches, leaf area which produced more photosynthates and that had reflected in higher dry matter, number of bolls, boll weight, seed cotton yield plant^{-1} and ultimately higher seed cotton yield. The above results also corroborate the findings by Singh *et al*. (2014) [22], Paslawar and Deotalu (2015) [18], Pandagale *et al*. (2015) [17], Jadhav *et al*. (2015) [12], Hargilas and Saini (2018) [9] and D. Lakshmi Kalyani *et al*. (2018) [4].

Interaction effect of weather variability and plant density

Interaction effect of weather variability and plant density (S X P) was found significant during 2014-15 (Table 2). Remaining interaction effects were non significant during 2013-14, 2014-15 and in pooled analysis.

The treatment combination of S_1P_3 (monsoon sowing with plant density of 45 X 10 cm, 2.22 lakh plants ha^{-1}) recorded significantly highest seed cotton yield (kg ha^{-1}) over rest of the treatment combinations.

As regards the seed cotton yield, with the exception of S X P interaction during 2014-15, remaining interactions were non significant.

Table 2: Seed cotton and stalk yield (kg ha^{-1}) as influenced by S X P interaction during 2014-15

	Seed cotton yield			**Cotton stalk yield**		
S/P	**P_1**	**P_2**	**P_3**	**P_1**	**P_2**	**P_3**
S_1	1139	1390	1547	2208	3234	3357
S_2	943	1001	1270	1687	2461	3023
S.E(m)±	34			76		
CD (P=0.05)	106			240		

Stalk yield

Data on cotton stalk yield as influenced by different treatments are presented in Table 1. The mean stalk yield of cotton was 3770, 2662 and 3216 kg ha^{-1} during 2013-14, 2014-15 and in pooled analysis, respectively.

Cotton stalk yield was significantly decreased with the late sowing. Significantly higher stalk yield of cotton was recorded in monsoon sowing (4096 and 2933 kg ha^{-1}) as compared to late sowing (3445 and 2390 kg ha^{-1}). Similar trend of the result was observed during 2013-14, 2014-15 and in pooled data (3514 and 2917 kg ha^{-1}). Hallikeri *et al*. (2009) [8] and Pinky Patel *et al*. (2016) [20] also observed that early sown crop recorded higher stalk yield over the subsequent late sowing.

Difference in stalk yield due to different planting densities were significant. High population density of 45 X 10cm (2.22 lakh plants ha^{-1}) recorded significantly highest stalk yield (4674, 3190 and 3932 kg ha^{-1}) followed by 60X 10 cm (3819, 2847 and 3333 kg ha^{-1}) and 60 X 15 cm (2818, 1948 and 2383 kg ha^{-1}) during 2013-14, 2014-15 and in pooled result. Similar results were also observed by Hake (2017) [7] and Kharagkharate *et al*. (2017) [14].

The concurrent increase in fertilizer regimes resulted in significant increase in stalk yield over its preceding lower levels during both the years and in pooled data. Significantly highest stalk yield was observed in 120:60:60 NPK kg ha^{-1} followed by 90:45: 45 NPK kg ha^{-1} and least stalk yield in 60:30:30 NPK kg ha^{-1}. Application of higher quantity of fertilizer, increased vegetative attributes and accumulation of dry matter plant^{-1} was higher. These results are in conformity with findings of Hiwale *et al*. (2016) [10].

Interaction effect of weather variability and plant density

Weather variability and plant density interaction (S X P) was found significant in respect of stalk yield during 2014-15 (Table 2).

Data presented in Table 2 indicated that interaction of S_1P_3 i.e. monsoon sowing with plant density of 45 x 10 cm (2.22 lakh plants ha^{-1}) recorded significantly higher stalk yield (3357 kg ha^{-1}) and it was on par with treatment combination of S_1P_2 (monsoon sowing with plant density of 1.66 lakh plants ha^{-1}).

Nitrogen uptake

Total uptake of nitrogen was calculated by considering the nitrogen uptake by cotton seed as well as cotton stalk and the data as influenced by various treatments are presented in Table 3. Varying sowing time (weather variability), plant density and fertilizer regime significantly influenced the nitrogen uptake of seed, stalk and total uptake. Mean uptake of nitrogen by cotton seed, cotton stalk and total uptake were more (42.89, 26.87 and 69.76 kg ha^{-1}) in 2013-14 season than (29.35, 15.82 and 45.20 kg ha^{-1}) during 2013-14 and 2014-15, respectively.

Under weather variability, uptake of nitrogen by cotton seed, cotton stalk and its total uptake was significantly higher with monsoon sowing (S_1) as compared to late sowing (S_2) during both the years of study. Higher growth, yield and total biomass output in crop under monsoon sowing removed greater amount of nitrogen from soil.

Table 3: Influence of weather variability, plant density and fertilizer regime on nitrogen uptake (kg ha^{-1}) by seed, stalk and total uptake

Treatment	2013-14			2014-15		
	Seed	Stalk	Total	Seed	Stalk	Total
Main plot treatment						
A) Weather variability						
S_1- Monsoon sowing	49.32	29.60	78.91	33.70	17.74	51.513
S_2- Late sowing	36.46	24.14	60.60	25.00	13.90	38.893
SE(m)±	0.99	0.83	1.10	0.80	0.46	0.830
CD (P=0.05)	3.13	2.60	3.46	2.51	1.45	2.614
B) Plant density						
P_1- 60 X 15 cm (1.11 lakh plants ha^{-1})	35.58	20.75	56.33	26.77	12.26	39.03
P_2- 60 X 10 cm (1.66 lakh plants ha^{-1})	43.38	27.36	70.74	29.02	16.85	45.87
P_3- 45X 10 cm (2.22 lakh plants ha^{-1})	49.71	32.48	82.20	32.25	18.35	50.71
SE(m)±	1.22	1.01	1.34	0.97	0.56	1.02
CD (P=0.05)	3.84	3.18	4.23	3.07	1.77	3.20
Sub plot treatment						
Fertilizer regime						
F_1- RDF (60:30:30 NPK kg ha^{-1})	37.00	22.71	59.71	23.76	13.05	36.82
F_2-150%RDF(90:45:45 NPK kg ha^{-1})	43.60	27.23	70.83	31.13	16.46	47.70
F_3-200%RDF(120:60:60 NPK kg ha^{-1})	48.07	30.66	78.72	33.14	17.95	51.09
SE(m)±	1.02	0.59	1.27	0.75	0.51	1.21
CD (P=0.05)	2.98	1.71	3.71	2.20	1.49	3.53
Interaction						
S X P						
SE(m)±	1.72	1.43	1.90	1.38	0.80	1.44
CD (P=0.05)	NS	NS	NS	NS	NS	NS
SX F						
SE(m)±	1.44	0.83	1.80	1.06	0.72	1.71
CD (P=0.05)	NS	NS	NS	NS	NS	NS
P X F						
SE(m)±	1.77	1.01	2.20	1.30	0.88	2.10
CD (P=0.05)	NS	NS	NS	NS	NS	NS
SX P X F						
SE(m)±	2.50	1.43	3.11	1.84	1.25	2.96
CD (P=0.05)	NS	NS	NS	NS	NS	NS
GM	42.89	26.87	69.76	29.35	15.82	45.20

Among the various plant densities, uptake of nitrogen by cotton seed, cotton stalk and its total uptake was significantly higher with plant density of 45 X 10 cm (2.22 lakh plants ha^{-1}) as compared to remaining two plant densities of 60 X 10 cm (1.66 lakh plants ha^{-1}) and 60 X 15 cm (1.11 lakh plants ha^{-1}). As regards uptake of nitrogen by cotton seed, the latter two were at par during 2014-15. Higher uptake of nitrogen in plant density of 45 X 10 cm was due to higher total dry matter production ha^{-1} by its higher plant population (2.22 lakh pl. ha^{-1}). Similar results were observed by Dhillion *et al*. (2006) [6], Sisodia and Khamparia (2007) [23] and Manjunatha *et al*. (2010) [16] and Khargkharate *et al*. (2017) [14].

During 2013-14, among the various fertilizer regimes, uptake of nitrogen by cotton seed, cotton stalk and also total nitrogen uptake was significantly higher under application of 200 % RDF(120:60:60 NPK kg ha^{-1}) as compared to 150 % RDF(90:45:45 NPK kg ha^{-1}) and 100% RDF (60:30:30 NPK kg ha^{-1}) which recorded the lowest values of nitrogen uptake. During 2014-15 also fertilizer regime of 120:60:60 NPK kg ha^{-1} recorded significantly higher uptake of nitrogen by cotton seed, cotton stalk and its total uptake but it was at par with 90:45:45 NPK kg ha^{-1} for uptake of nitrogen by cotton seed, cotton stalk and total uptake also. Higher fertilizer regime induced increased growth, yield attributes and dry matter production under higher nitrogen nutrient regime causing greater nitrogen removal. Similar results were observed by Hosamani *et al*. (2013) [11] and Sankaranarayanan *et al*. (2018) [21].

All interaction effects were found to be statistically non-significant as regards uptake of nitrogen by cotton seed, cotton stalk and also total nitrogen uptake during both years of experimentation.

Phosphorus Uptake

Effect of weather variability, plant density and fertilizer regime on uptake of phosphorus by cotton seed, stalk and total phosphorus uptake by cotton proved significant (Table 4) during both years. Mean uptake of phosphorus by seed cotton was 7.24 and 4.87 kg ha^{-1}, cotton stalk 11.26 and 7.22 kg ha^{-1} and total uptake 18.50 and 12.10 kg ha^{-1}, respectively during 2013-14 and 2014-15.

Uptake of phosphorus by cotton seed, cotton stalk and its total uptake was significantly higher with monsoon sowing (S_1) as compared to late sowing (S_2) during both the years of study.

Uptake of phosphorus by cotton seed, cotton stalk and its total uptake was significantly higher with plant density of 45 X10 cm (2.22 lakh plants ha^{-1}) as compared to remaining two plant densities of 60 X 10 cm (1.66 lakh plants ha^{-1}) and 60 X 15 cm (1.11 lakh plants ha^{-1}). For uptake of phosphorus by cotton seed, plant densities of 60 X 15 cm (1.11 lakh plants ha^{-1}) and 60 X 10 cm (1.66 lakh plants ha^{-1}) were at par during 2014-15. Similarly for uptake of phosphorus by cotton stalk plant densities of 60 X 10 cm(1.66 lakh plants ha^{-1}) and 45 X10 cm (2.22 lakh plants ha^{-1}) varied non-significantly during 2014-15. Higher uptake of phosphorus in high density of 45 X 10 cm (2. 22 lakh pl. ha^{-1}) was due to the higher dry matter production ha^{-1} under higher population density. Similar results were observed by Dhillion *et al*. (2006) [6], Sisodia and Khamparia (2007) [23] and Manjunatha *et al*. (2010) [16] and Khargkharate *et al*. (2017) [14].

During 2013-14 season uptake of phosphorus by cotton seed, cotton stalk and also total phosphorus uptake was significantly higher under application of 120:60:60 NPK kg ha^{-1} (F_3) as compared to 90:45:45 NPK kg ha^{-1} (F_2) and 60:30:30 NPK kg ha^{-1} (F_1). Lowest phosphorus uptake was with F_1. During 2014-15 also fertilizer regime of 120:60:60 NPK kg ha^{-1} recorded significantly higher uptake of phosphorus by cotton seed, cotton stalk and its total uptake but it was at par with 90:45:45 NPK kg ha^{-1} for uptake of phosphorus by cotton seed, cotton stalk and total uptake also. Higher uptake of phosphorus in higher fertilizer regimes was due to overall higher dry matter production ha^{-1}. Similar results were observed by Hosamani *et al.* (2013) [11] and Sankaranarayanan *et al*. (2018) [21].

Table 4: Influence of weather variability, plant density and fertilizer regime on phosphorus uptake (kg ha^{-1}) by seed, stalk and total uptake

Treatments	2013-14			2014-15		
	Seed	**Stalk**	**Total**	**Seed**	**Stalk**	**Total**
Main plot treatment						
A) Weather variability						
S_1- Monsoon sowing	8.28	12.84	21.11	5.57	8.41	13.98
S_2- Late sowing	6.20	9.68	15.89	4.18	6.04	10.22
SE(m)±	0.14	0.38	0.41	0.11	0.23	0.27
CD (P=0.05)	0.45	1.20	1.29	0.33	0.73	0.84
B) Plant density						
P_1- 60 X 15 cm (1.11 lakh plants ha^{-1})	6.08	9.69	15.77	4.49	6.09	10.58
P_2- 60 X 10 cm (1.66 lakh plants ha^{-1})	7.34	11.30	18.64	4.75	7.52	12.27
P_3- 45X 10 cm (2.22 lakh plants ha^{-1})	8.30	12.79	21.09	5.38	8.06	13.44
SE(m)±	0.17	0.47	0.50	0.13	0.28	0.33
CD (P=0.05)	0.55	1.47	1.58	0.41	0.89	1.03
Sub plot treatment						
Fertilizer regime						
F_1- RDF (60:30:30 NPK kg ha^{-1})	5.86	8.47	14.32	3.76	5.23	8.99
F_2-150%RDF (90:45:45 NPK kg ha^{-1})	7.45	11.42	18.87	5.29	7.95	13.23
F_3- 200%RDF(120:60:60 NPK kg ha^{-1})	8.42	13.89	22.31	5.58	8.49	14.07
SE(m)±	0.20	0.30	0.37	0.12	0.27	0.30
CD (P=0.05)	0.59	0.89	1.07	0.34	0.78	0.88
Interaction						
S X P						
SE(m)±	0.25	0.66	0.71	0.18	0.40	0.46
CD (P=0.05)	NS	NS	NS	NS	NS	NS
SX F						
SE(m)±	0.29	0.43	0.52	0.17	0.38	0.43
CD (P=0.05)	NS	NS	NS	NS	NS	NS
P X F						
SE(m)±	0.35	0.53	0.63	0.20	0.46	0.53
CD (P=0.05)	NS	NS	NS	NS	NS	NS
SX P X F						
SE(m)±	0.50	0.74	0.89	0.29	0.65	0.74
CD (P=0.05)	NS	NS	NS	NS	NS	NS
GM	7.24	11.26	18.50	4.87	7.22	12.10

Interaction effects were found to be non-significant during both the years of study.

Potassium uptake

Data in respect of potassium uptake by cotton was significantly influenced by various treatments and is presented in Table 5. Mean uptake of potassium by seed cotton (10.50 and 6.69 kg ha^{-1}), cotton stalk (28.86 and 19.62 kg ha^{-1}) and total potassium uptake (39.35 and 26.31 kg ha^{-1}) was more during the first season as compared to the second season.

Table 5: Influence of weather variability, plant density and fertilizer regime on potassium uptake (kg ha^{-1}) by seed, stalk and total uptake

Treatment	2013-14			2014-15		
	Seed	**Stalk**	**Total**	**Seed**	**Stalk**	**Total**
Main plot treatment						
A) Weather variability						
S_1- Monsoon sowing	12.72	33.69	46.40	7.94	23.06	31.00
S_2- Late sowing	8.53	25.06	33.58	5.43	16.19	21.62
SE(m)±	0.28	0.85	0.84	0.13	0.42	0.49
CD (P=0.05)	0.87	2.68	2.64	0.42	1.32	1.55
B) Plant density						
P_1- 60 X 15 cm (1.11 lakh plants ha^{-1})	8.89	23.57	32.47	6.13	15.51	21.65
P_2- 60 X 10 cm (1.66 lakh plants ha^{-1})	10.82	29.50	40.33	6.73	21.04	27.77

P_3- 45X 10 cm (2.22 lakh plants ha^{-1})	12.15	35.04	47.19	7.19	22.32	29.52
SE(m)±	0.34	1.04	1.03	0.16	0.51	0.60
CD (P=0.05)	1.07	3.28	3.23	0.52	1.62	1.90
Sub plot treatment						
Fertilizer regime						
F_1- RDF (60:30:30 NPK kg ha^{-1})	9.15	25.21	34.36	5.06	16.18	21.24
F_2-150%RDF (90:45:45 NPK kg ha^{-1})	10.94	29.79	40.73	7.34	20.51	27.85
F_3- 200%RDF(120:60:60 NPK kg ha^{-1})	11.79	33.11	44.89	7.66	22.19	29.85
SE(m)±	0.31	0.58	0.68	0.13	0.59	0.71
CD (P=0.05)	0.91	1.70	1.97	0.37	1.73	2.06
Interaction						
S X P						
SE(m)±	0.48	1.47	1.45	0.23	0.73	0.85
CD (P=0.05)	NS	NS	NS	NS	NS	NS
SX F						
SE(m)±	0.44	0.82	0.95	0.18	0.84	1.00
CD (P=0.05)	NS	NS	NS	0.53	NS	NS
P X F						
SE(m)±	0.54	1.01	1.17	1.45	1.73	1.45
CD (P=0.05)	NS	NS	NS	NS	NS	NS
SX P X F						
SE(m)±	0.76	1.43	1.65	0.31	1.45	1.73
CD (P=0.05)	NS	NS	NS	NS	NS	NS
GM	10.62	29.37	39.99	6.69	19.62	26.31

Potassium is known for its significance in improving the quality of produce as well as to create tolerance to moisture stress in plants. The dissolved organic acids in the soils by incorporation of applied organics supports and release more of K ions to the plants. The enhanced mobility of potassium ions in the soil helps plant to get absorbed more nutrients. This results into accumulation of more K ions in the plants and enhanced plant uptake. The same has been indicated in the data generated after harvest of cotton.

Potassium uptake by cotton seed, cotton stalk and its total uptake was significantly influenced by weather variability induced through varying sowing time wherein uptake of potassium by cotton seed, cotton stalk and total potassium uptake was significantly higher by crop under monsoon sowing (S_1) as compared to late sowing (S_2) during both the years of study.

In cotton seed, cotton stalk and in total potassium uptake was significantly higher with plant density of 45 X10 cm (2. 22 lakh plants ha^{-1}) than remaining two plant densities of 60 X 10 cm (1. 66 lakh plants ha^{-1}) and 60 X 15 cm (1.11 lakh plants ha^{-1}). Potassium uptake by cotton seed, cotton stalk and total potassium uptake was statistically on par in plant density of 1.66 lakh plants ha^{-1} and 2. 22 lakh plants ha^{-1} during 2014-15. Higher plant density per unit area removed greater amount of potassium from soil. Similar results was indicated by Sisodia and Khamparia (2007) [23] and Manjunatha *et al*. (2010) [16].

Among the various fertilizer regimes, uptake of potassium in cotton seed, cotton stalk and also total potassium uptake was significantly higher with application of 120:60:60 NPK kg ha^{-1} as compared to 90:45:45 NPK kg ha^{-1} and 60:30:30 NPK kg ha^{-1}, excepting that fertilizer regimes of 120:60:60 NPK kg ha^{-1} and 90:45:45 NPK kg ha^{-1} were at par with each other for potassium uptake in cotton seed during 2013-14 and for potassium uptake in cotton seed, cotton stalk and also its total uptake during 2014-15 season. Higher potassium uptake with higher fertilizer regime was due to overall better growth and development of crop and resultant greater potassium removal by its higher biomass produced ha^{-1}. Similar results were observed by Sisodia and Khamparia (2007) [23] who observed that every level of increase in fertility, significantly increased uptake of K from soil. Hosmani *et al.* (2013) [11] and Sankaranarayanan *et al*. (2018) [21] also recorded similar observation.

Interaction effect of weather variability and fertilizer regime

Interaction effect was found to be statistically non-significant during both the years of study for uptake of potassium by cotton seed, cotton stalk and also its total uptake except interaction of S X F during 2014-15.

Interaction effect of weather variability and fertilizer regime was found to be significant (Table 6). Treatment combination of S_1F_3 (monsoon sowing with 120:60:60 NPK kg ha^{-1}) recorded significantly higher uptake of potassium by cotton seed and it was statistically comparable to S_1F_2 (monsoon sowing with 90:45:45 NPK kg ha^{-1}).

Table 6: Uptake of potassium by cotton seed as influenced by S X F interaction during 2014-15

S/ F	F_1	F_2	F_3
S_1	5.97	8.76	9.09
S_2	4.16	5.92	6.22
S.E(m)±	0.18		
CD (P=0.05)	0.53		

Conclusion

It is concluded that seed cotton and stalk yield and total uptake of N, P and K was higher in monsoon sowing, 200% plant density (2.22 lakh ha^{-1}) and in 200% RDF (120:60:60 NPK kg ha^{-1}). The treatment combination of monsoon sowing with 200% plant density (S_1P_3) recorded higher seed cotton and stalk yield during *kharif* season of 2014-15. Potassium uptake of treatment 150% plant density as well as fertilizer regimes of 150% RDF was on par with the higher plant density and 200%RDF. Uptake of potassium was higher in treatment combination of monsoon sowing with 200% RDF (S_1F_3) and on par with monsoon sowing with 150% RDF (S_1F_2) during season of 2014-15.

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