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Mobility of N, P and K and root growth of Bt and non-Bt cotton in clayey soil under different NPK levels

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ABSTRACT

The mobility of applied nutrients in soil and root growth determines the interception and uptake of nutrients by crop. Present investigation includes two pot culture experiments under glass house condition. The objective of first experiment was to study the mobility of N, P and K in soil profile of cotton in respect to different NPK levels; whereas, in second experiment root growth of Bt and non-Bt cotton hybrids were studied under different NPK levels. The first experiment comprised of four NPK levels, i.e. control- 00:00:00, 50:25:25, 62.5:31.25:31.25 and 75:37.5:37.5 kg N, P_2O_5, K_2O ha^{-1} and four depth of sampling, i.e. 15, 30, 45 and 60 cm in soil column. Whereas, in second experiment Bt and non-Bt counterpart of same cotton hybrid were evaluated for root growth under above mention NPK levels. Both the experiments consist of four set of replications and experimental design was FRBD. Results illustrate that, concentration of available N, P and K in soil profile of cotton significantly increased with the highest rate of NPK than control. Irrespective of NPK levels, shallow depth of sampling (15 cm) recorded maximum concentration of available N, P and K throughout the period of experimentation. However, N was mobile up to 60 cm depth and K up to 45 cm depth in 90 days; whereas P mobility was restricted only up to 15 cm depth even in 90 days. Each increase in NPK level increased the downward mobility of N in soil by 15 cm at 30 days after fertilizer application. The increased in available P content with increase in NPK levels remains restricted to placement zone (15 cm) only and its downward mobility in soil profile over the period in response to NPK levels was absent. However, K was found mobile up to 45 cm depth under highest level of NPK at 30 days after fertilizer application. As regards root growth, Bt hybrid recorded longest root at initial stage whereas, at later stage it was in non-Bt. Application of the highest rate of NPK significantly increased root length over lower levels.

Key words: *Mobility of NPK, root growth, Bt and non-Bt cotton, NPK levels*

Introduction

The fertilizers are applied as a surface application or drilled through ferti-cum seed drill at the time of sowing or as a band application at shallow depth of 5 to 7 cm. But, crop uptake efficiency of applied nutrients and thereby growth and yield is greatly determined by mobility of specific nutrient in soil, particularly its downward mobility in deep-rooted crops like cotton. Besides this, losses like volatilization, runoff, fixation, leaching and immobilization also affects the efficiency of applied nutrients. Shallow rooted crops are efficient in utilizing slow mobile or even immobile nutrients placed at upper layer of soil. However, deep-rooted crops like cotton are unable to intercept shallow placed slow or immobile nutrients particularly at later stages of growth. That is because of root hair decay in topsoil and advancement of active root system at deeper layer at later stages of growth. In addition, low soil moisture at top layers of soil after cessation of rainfall restricts the mass flow and diffusion of nutrients towards root hair and consequently their uptake by cotton (Mai *et al*., 2018). Thus, deep-rooted crops are more dependent on inherent soil fertility for immobile nutrient at later stages of growth than shallow rooted. Mobility of nutrients in soil profile depends on several factor's *viz*., cation exchange capacity of soil, organic matter content, type of clay, presence of nutrient fixing minerals, frequency and duration of wetting and drying cycles, drainage and soil compaction (Zadeh *et al*., 2008). Growth and productivity of cotton positively related with length and proliferation of root system in deeper soil layers, and root growth is determined by availability of nutrients to roots (Chen *et al*., 2020). The fertilizer rates itself can also influence the mobility and in that way availability of nutrients and root growth of crop. The information on mobility of nutrient in soil and root growth of cotton is relatively scarce. Therefore, the purpose of this research was to study the influence of NPK levels on downward mobility of N, P and K through soil column with respect to root growth of Bt and non-Bt cotton.

Materials and Methods

This study consists of two pot culture experiments. The first experiment was intended to study the influence of NPK levels on mobility of N, P and K in soil profile of cotton. Whereas, second experiment was formulated to study the periodic root growth of Bt and non-Bt cotton in respect to NPK levels. Both the experiment was conducted under glass house condition at Agronomy Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during rainy season of 2009-10. The experimental site is situated at 22° 42′ N latitude and 77° 02′ E longitude and at an altitude of 307.4 meters above mean sea level. Polyethylene pots of 120 cm height, 25 cm diameter and 100 µ thickness were used for these experiments. Each pot was filled with 70 kg air dried soil of 0-30 cm depth. The soil used for experimentation was clayey in texture (*Vertisols*), low in organic carbon (0.40%), slightly alkaline in reaction (pH 8.5), normal in electrical conductivity (0.40 dSm^{-1}) low in available nitrogen (150.5 kg ha^{-1}) and phosphorus (15.9 kg ha^{-1}) and fairly high in available potassium (394.5 kg ha^{-1}). To obtain required density of soil in pot, the soil was filled in layers and compacted with wooden hammer. The support was provided to each pot to keep it straight and avoid lodging. Small holes of 5 mm diameter were prepared around and below the pots before filling soil to maintain aeration and drain out excess water after irrigation. Two seeds of cotton were dibbled in each pot to avoid the risk of emergence and thinning was done after complete emergence to maintain single plant in each bag. Watering was done at alternate day till complete emergence of cotton and thereafter at weekly interval to maintain optimum moisture in soil column. Equal quantity of water was added to each pot as per the need of crop. The treatment wise amount of fertilizer required for each pot was calculated as per soil weight. Fertilizer used to provide required quantity of N, P and K were urea, single super phosphate and muriate of potash, respectively. Both the experiments were replicated four times and data were analyzed by applying FRBD.

The mobility study consist of sixteen treatment combinations of four NPK levels i.e. control-00:00:00 (F_0), 50:25:25 (F_1), 62.5:31.25:31.25 (F_2) and 75:37.5:37.5 (F_3) kg N, P_2O_5, K_2O ha^{-1} and four depth of sampling i.e. 15 cm (D_1), 30 cm (D_2), 45 cm (D_3) and 60 cm (D_4) to test the downward mobility of nutrient in soil profile of cotton at 30, 60 and 90 days time interval. Full dose of NPK as per calculated amount for each treatment was applied before dibbling of cotton seed and well mixed with upper 7 cm of soil. Bt cotton hybrid NCS-145 (BG II) was used for this study. Seed sampler was used to take soil samples from different layers of soil column in polyethylene pots. The soil samples were initially air dried, powdered and later oven dried at 105 °C and analyzed for available, N, P and K. Available nitrogen was determined by alkaline permanganate method using microprocessor based automatic distillation system (Subbiah and Asija, 1956). Available phosphorus was determined by Olsen's method using 0.5 M sodium bi-carbonate as an extractant using UV based double beam spectrophotometer (Olsen and Sommers, 1982) and available potassium was determined by neutral normal ammonium acetate method using flame photometer (Knudsen and Peterson, 1982).

The root study consist of eight treatment combinations of Bt (BG II) (V_1) and non-Bt (V_2) of cotton hybrid NCS-145 and four fertilizer levels, i.e. control- 00:00:00 (F_0), 50:25:25 (F_1), 62.5:31.25:31.25 (F_2) and 75:37.5:37.5 (F_3) kg N, P_2O_5, K_2O ha^{-1}. In this experiment half dose of N and full dose of P and K were applied at the time of dibbling of seed and remaining half dose of N was applied 30 days after sowing (DAS). Observation of root length was recorded at 30, 60 and 90 DAS. For this polyethylene pots were tore with blade without disturbing the inner soil and roots were exposed by washing the soil around by water flow. Length of root was measured from collar region to the end of main root.

Results and Discussion

Study on mobility of N, P and K

Mobility of N, P and K in soil column of cotton as influenced by NPK levels over the period is presented in Table 1. Perusal of data indicates that irrespective of treatment, concentration of available N, P and K in soil decreased over the period, except in control (F_0) where concentration of these nutrients remained more or less stable. The decrease in available N concentration might be due to volatilization losses and trapping of NH_4^+ ion in clay crystal micelle. However, depletion in available P and K might be due to its fixation. Beside this uptake by cotton plant might have major share in this decrease.

Effect of NPK levels

Application of 75:37.5:37.5 kg NPK ha^{-1} recorded significantly higher concentration of available N, P and K in soil than control at all the stages of sampling but remain at par with 62.5:31.25:31.25 kg NPK ha^{-1} at all the stages of sampling and with 50:25:25 kg NPK ha^{-1} for available P at 90th day sampling. The maximum concentration of N, P and K

Table 1. Mobility of N, P and K in soil profile of cotton as influenced by different NPK levels

NPK levels	30 DAS					60 DAS					90 DAS				
	Sampling depth (cm)														
	D_1	D_2	D_3	D_4	**Mean**	D_1	D_2	D_3	D_4	**Mean**	D_1	D_2	D_3	D_4	**Mean**
	Available nitrogen (ppm)														
F_0	74.44	75.44	74.44	73.44	**74.44**	73.70	75.16	74.28	73.44	**74.14**	73.70	75.04	72.85	72.52	**73.53**
F_1	99.28	91.61	75.62	74.62	**85.28**	90.07	88.22	74.63	74.89	**81.95**	78.79	77.07	75.03	73.54	**76.11**
F_2	102.63	94.03	83.24	79.24	**89.78**	93.10	91.11	81.75	78.01	**85.99**	81.85	79.99	81.68	78.19	**80.43**
F_3	106.70	98.30	87.49	83.49	**94.00**	96.90	95.14	85.71	81.98	**89.93**	85.40	83.75	85.39	81.90	**84.11**
Mean	**95.76**	**89.85**	**80.20**	**77.70**		**88.44**	**87.41**	**79.09**	**77.08**		**79.94**	**78.96**	**78.74**	**76.54**	
		Levels	Depth	F x D			Levels	Depth	F x D			Levels	Depth	F x D	
S.Em ±		1.489	1.489	2.978			1.408	1.408	2.817			1.317	1.317	2.634	
C.D. at 5%		4.241	4.241	8.481			4.012	4.012	NS			3.751	NS	NS	
	Available phosphorus (ppm)														
F_0	3.50	3.50	3.54	3.53	**3.51**	3.49	3.49	3.52	3.52	**3.50**	3.49	3.51	3.48	3.50	**3.49**
F_1	6.24	3.60	3.54	3.53	**4.22**	4.36	3.62	3.57	3.53	**3.77**	3.79	3.77	3.65	3.54	**3.69**
F_2	6.74	3.56	3.56	3.57	**4.36**	4.72	3.59	3.60	3.57	**3.87**	4.11	3.63	3.63	3.59	**3.74**
F_3	7.06	3.59	3.55	3.46	**4.41**	4.94	3.62	3.59	3.46	**3.90**	4.30	3.62	3.66	3.48	**3.76**
Mean	**5.88**	**3.56**	**3.55**	**3.52**		**4.38**	**3.58**	**3.57**	**3.52**		**3.92**	**3.63**	**3.60**	**3.53**	
		Levels	Depth	F x D			Levels	Depth	F x D			Levels	Depth	F x D	
S.Em ±		0.052	0.052	0.100			0.050	0.050	0.100			0.049	0.049	0.097	
C.D. at 5%		0.147	0.147	0.290			0.142	0.142	0.285			0.139	0.139	0.278	
	Available potassium (ppm)														
F_0	139.85	139.85	141.42	141.29	**140.60**	139.15	139.15	140.71	140.58	**139.90**	138.73	138.73	140.29	140.18	**139.48**
F_1	166.87	159.80	143.60	141.40	**152.92**	156.20	150.08	144.51	142.08	**148.22**	147.29	144.07	141.88	140.57	**143.45**
F_2	170.80	163.70	147.50	142.21	**156.05**	159.95	153.82	148.26	142.87	**151.22**	150.89	147.67	144.97	142.87	**146.60**
F_3	173.10	166.09	149.85	144.61	**158.41**	162.18	156.12	150.51	145.27	**153.52**	153.03	149.88	147.17	145.27	**148.84**
Mean	**162.65**	**157.36**	**145.59**	**142.38**		**154.37**	**149.79**	**146.00**	**142.70**		**147.48**	**145.09**	**143.58**	**142.22**	
		Levels	Depth	F x D			Levels	Depth	F x D			Levels	Depth	F x D	
S.Em ±		1.396	1.396	2.792			1.467	1.467	2.933			1.543	1.543	3.086	
C.D. at 5%		3.977	3.977	7.953			4.177	4.177	NS			4.395	4.395	NS	

with higher dose of fertilizer, i.e. 75:37.5:37.5 kg NPK ha^{-1} was factual. However, significant decrease in difference between higher and lower fertilizer dose at 90 DAS, specially with respect to available P indicates the fixation of applied P in soil than K and N. The increased in NH_4^+ and NO_3^- N concentration in soil profile of sugarcane with increasing N rates was observed by Bahmani *et al.* (2009)

Effect of sampling depth

Sampling depth of 15 cm (D_1) recorded significantly higher concentration of available N at 30th and 60th days of sampling, however, at 60th day sampling it remain at par with sampling depth of 30 cm. Whereas at 90th day result was found non-significant. This indicates fair movement of applied N in soil up to 30 cm depth after 60 days of its application and up to 60 cm depth after 90 days of application. Movement of N noted in this result might be in the form of NO_3^- as negative charged nitrate nitrogen repelled by soil particles and move freely along with soil water in soil profile. However, positive charged NH_4^+ ions tightly held by negatively charged clay micelle. Zadeh *et al.* (2008) opined that NO_3^- form of N is responsible for downward mobility of N in less compacted aerated soil profile.

Significantly higher concentration of available phosphorus was observed at upper layer, i.e. 15 cm sampling depth (D_1) than lower depths at all the stages of sampling. This result indicates poor and restricted mobility of applied P for only 15 cm depth in 90 days; which affect the availability of phosphorus at rooting depth below 15 cm and is major limitation for its uptake. Thus, to increase phosphorus use efficiency it should be placed at lower depth at the time of sowing or before sowing as root interception of P is prime technique of uptake.

As regards K, sampling depth of 15 cm (D_1) recorded significantly maximum available potassium concentration in soil at all the stages of sampling; however on 90th day sampling it was comparable with 30 cm (D_2) and 45 cm (D_3) sampling depths. This result conveys that K is somewhat mobile in soil, i.e. up to 45 cm in 90 days.

On the basis of above results N, P and K can be arranged for their mobility in soil profile as follows.

Nitrogen > Potassium > Phosphorus

Table 2. Root length of Bt and non-Bt cotton hybrids as influenced by different NPK levels

Treatments	30 DAS	60 DAS	90 DAS
Cotton hybrids			
V_1- Bt hybrid	20.48	44.63	64.25
V_2 - non-Bt hybrid	18.75	39.63	82.75
S.Em ±	0.62	1.12	1.17
C.D. at 5%	NS	3.29	3.44
NPK kg ha^{-1}			
F_0- 00:00:00 (Control)	17.70	38.88	58.50
F_1- 50:25:25	17.33	39.88	63.00
F_2- 62.5:31.25:31.25	18.55	42.75	77.50
F_3- 75:37.5:37.5	24.89	47.00	95.00
S.Em ±	0.87	1.58	1.65
C.D. at 5%	2.56	4.65	4.86

Interaction effect

Interaction effect was significant for available N and K on 30th day of sampling and for available P at all the stages of sampling. The interaction data throw more light on movement of nutrients in soil with respect to NPK levels. The NPK level F_1, F_2 and F_3 significantly increased available N content up to 30 cm, 45 cm and 60 cm soil depth, respectively over respective depth of sampling in control (F_0) at 30 days after fertilizer application (DAFA). This result signifies that each 25 per cent increase in N level could increase the downward mobility of applied N by 15 cm in soil profile. Bahmani *et al.* (2009) reported that concentration of NO_3^- N increased at lower depth of soil profile with the advancement of time and this increase is more prominent at higher level of N.

Increase in NPK level did not show the significant improvement in P content at 30 cm and subsequent depth of sampling over respective depth of sampling in control at 30, 60 and 90 DAFA. However, significant increase in available P content with each increase in NPK level was observed at 15 cm sampling depth at 30 DAFA. Whereas, at 60 and 90 DAFA at 15 cm sampling depth significant increased in P content was noted up to fertilizer level F_2. This result indicates that increase in P level increased its availability only in placement zone, and it did not influence its downward movement in soil profile. Thus cotton is more dependent on available P in subsoil as water stress encountered at topsoil restrict availability of applied P and also due to presence of active roots in subsoil at later stages of growth (Wang *et al.*, 2010). Deep-rooted crop like cotton may experience P deficiency at later stages of growth despite application of higher doses of P, if inherent availability of P is low.

In case of K, the NPK level F_1 and F_2 significantly increased available K content up to 30 cm depth over respective depth of sampling in control at 30 DAFA. However, fertilizer level F_3 significantly increased K availability up to 45 cm depth over respective depth of sampling in control at 30 DAFA. Result obtained in case of K indicates that higher level of K can extend downward mobility of K up to 45 cm depth in soil profile. Bell *et al*. (2009) also observed that application of K increased the K content at different soil depths (5, 15, 25 and 35 cm) than no application, but its content decreased as soil depth increased.

Study on root growth

Data regarding root length of Bt and non-Bt cotton hybrids as influenced by NPK levels are presented in Table 2.

Effect of cotton hybrids

Bt and non-Bt hybrids did not showed significant difference in root length at 30 DAS. Whereas, at 60 DAS significantly longest root was observed in Bt hybrid, however at 90 DAS corresponding result was obtained in non-Bt. Significant improvement in root length at 90 DAS in non-Bt version might be due to less fruit production and boll retention efficiency (Thakur, 2020) owing to bollworm damage (Thakur *et al*., 2018) which diverted assimilates for shoot and root growth. The higher root length densities and root length per unit area in non-Bt version than Bt was also reported by Tan *et al*. (2012).

Effect of NPK levels

Application of 75:37.5:37.5 kg NPK ha^{-1} resulted significantly longest root than rest of the NPK levels at all the stages of observations; however, at 60 DAS it was comparable with 62.5:31.25:31.25 kg NPK ha^{-1}. Moderate nitrogen fertilization can increase total root length density in different soil layers by 61 to 94 per cent than no application (Chen *et al*., 2018). Similarly, Mai *et al*. (2018) and Yong *et al*. (2009) observed that P and K deficiency inhibit root length and formation of lateral roots.

Conclusion

The increase in NPK level increased the downward mobility of N and K in soil profile of cotton; whereas, P mobility remains restricted to placement zone in clayey soil. Bt cotton has shallower root than non-Bt. Higher levels of NPK increased the root length of cotton.

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