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Soil Moisture Distribution, Nutrient Dynamics and Yield of Bt Cotton as Influenced by Split Application of Nutrients Through Fertigation

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ABSTRACT

A field experiment was conducted during the year 2011-12 and 2012-2013 at Department of Agronomy, Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola to study the soil moisture movement, nitrogen and potassium distribution and seed cotton yield due to split application of N and K fertilizers compared to conventional soil application of fertilizers in Bt cotton. The results indicated that soil moisture content was higher in soil layer of 0-30 cm vertically and it decreased with the increase in lateral distance from the emitter. Similarly it was higher in the surface layer (0-15 cm) and followed a decreasing trend with increase in depth. The mobility of nutrients was observed more in drip fertigation than conventional soil application method. The available nitrogen and potassium under drip fertigation levels showed increased concentrations as per the increment in the fertilizers doses from 50 to 125 per cent given through fertigation. There was a decrease in available N from dripper point both horizontally and vertically and highest available N was noticed at 125 per cent fertigation level at dripper point. The soil available K content was higher in the surface soil than in the subsoil. Drip fertigation at 125 per cent RDNK ha^{-1} had recorded higher seed cotton yield of 3680 Kg ha^{-1} and 3326 Kg ha^{-1} during 2011-12 and 2012-13 respectively. 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 both the years of study indicating 25 per cent fertilizer saving through fertigation when compared to conventional soil application of fertilizers.

Key words: *Fertigation, Cotton, Soil moisture, Nutrient dynamics*

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) as a white gold and king of fibre is the nature's gift to mankind and is mainly cultivated for its lint from time immemorial and also aptly called as "white gold". India is one of the major producers of cotton in the world with largest acreage of 9.59 M ha., but productivity as low as 505 Kg lint ha^{-1} as compared to global average of 735 Kg lint ha^{-1}[9]. Bt cotton hybrids now constitute about 90 per cent of the cotton area sown in the country.

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Water and nutrients are the two most important critical inputs for producing vigorous healthy plants and improving the yield of any crop. Among the different strategies of increasing agricultural productivity and increasing the water and nutrient use efficiency, drip irrigation and split application of nutrients through fertigation method gaining the importance nowadays. Drip fertigation provides an efficient method of fertilizer delivery and the availability of soil moisture and nutrients at root zone of the crops influences the uptake and yield of the crop. Deficit fertilizer supply has the major influence on production of fruiting sites on a cotton plant. Fruit retention is strongly dependent on the supply of N and K to the developing fruit. Method of fertilizer application along with appropriate schedule is one of the several factors that affect fertilizer use efficiency. Application of water soluble fertilizers through drip irrigation has gained widespread popularity as an efficient method for fertilizer application[5].The roots are developed extensively in a restricted volume of soil wetted by drip fertigation. Thus, drip fertigation system can place nutrients efficiently in wetted zone and are used by the plant from soil easily. It helps in achieving higher productivity and enhancing the quality of crop. However several basic principles must be followed in applying nutrients through irrigation system in order to place the fertilizer correctly with suitable movements in soil, decrease potential nutrient losses, avoid excessive fertilizer application and ultimately higher seed cotton yield of Bt cotton. In view of the above, it was felt appropriate to study the effect of split application of nutrients on nutrient dynamics and yield of Bt cotton.

MATERIALS AND METHODS

A field experiment was conducted during 2011-12 and 2012-13 at Department of Agronomy, Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) to study the effect of split application of N and K fertilizers on growth, yield attributes, soil moisture distribution and nutrient dynamics in Bt cotton and to economize the fertilizer requirement for Bt cotton under fertigation. The experiment was laid out in randomized block design with four replications. There were five treatments 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 of fertilizers given through fertigation and P as basal compared with 100 per cent soil application of fertilizers.

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. Cropping history of the experimental plot was almost practically uniform before conducting the experiment. Total rainfall during crop growth period was 481.3 mm in 36 rainy days during the year 2011-12 and it was 722.5 mm in 56 rainy days during the second year of study (2012-13).The experimental site was established with inline drip irrigation system (16 mm) lateral laid out at 120 cm with 60 cm dripper spacing. The recommended dose of fertilizers (N and K) was applied as per the treatments through fertigation tank of 90 lit. capacity. Phosphorus 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 and onion crop. 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. Irrigation water was applied through drip irrigation on alternate day at the rate of 100 per cent crop evapotranspiration level. The total water used by cotton through drip (including effective rainfall) was 469.32 mm and 622.3 mm during the year 2011-12 and 2012-13 respectively. The Bt cotton variety MRC-7326 was used for experimentation. The recommended dose of fertilizers was 100:50:50 NPK Kg ha^{-1}.The soil moisture content was estimated at 0,15,30 cm distance from the dripper point and to a depth of 0-15,15-30 and 30-45 cm below dripper to evaluate the vertical and horizontal uniformity of water spreading from the emitter in the crop root zone. Immediately after sowing, irrigation was given upto soaking of entire bed and subsequent irrigations were scheduled once in two days. For drip fertigation system the operating pressure was maintained at 1.0 kg cm^2. Drip irrigation was given as per the schedule once in two days based on cumulative pan evaporation. The volume of irrigation water to be applied per plant was determined by the following formula.

V(lpd) = (ETo x Kc x A x Wp)- (RE)

Where,

V - Volume of water applied (liter/day/plant)

ETo - Reference evapotranspiration(mm/day)

Kc - Crop factor

A - Area under crop (m^2)

(Plant to plant spacing)x(Row to row spacing)

Wp - Wetted area fraction

RE - Effective rainfall in mm

The net depth of water to be applied in drip irrigation of alternate day was determined by the following formula-

D= (ETo x Kc)- RE

Where,

D - Net depth of water to be required (mm)

ETo - Reference evapotranspiration (mm/day)

RE - Effective rainfall (mm)

Soil moisture content was estimated by gravimetric method. Soil samples were taken at a distance of 0, 15, 30 from dripper point (horizontal) and 0-15, 15-30 and 30-45 cm depth (vertical) for studying soil moisture irrigation regime during two consecutive irrigation cycles. This observation was done in rain free period. The values were expressed in per cent soil moisture by weight. The soil samples taken for moisture content were utilized for analysis.

RESULTS AND DISCUSSION

Soil moisture distribution

The data on soil moisture movement is given in Table 1 and graphically depicted in Fig. A. Adequate soil moisture availability ensures successful cotton production under any type of soil cultivation. The rate of applying water in drip irrigation is an important factor which governs moisture distribution in soil profile. The soil moisture distribution data given in Table 1 indicated that, below the dripper point, the moisture content 24 hrs. after drip irrigation showed higher soil moisture content in the top layer and progressively declined vertically in the bottom layer (30-45 cm).Similarly ,the moisture content also decreased horizontally from 0-30 cm. The higher moisture content of 32.9, 31.1, and 29.5 per cent was recorded near emitter point at 0-15 cm, 15-30 cm and 30-45 cm vertical depth respectively during the first year of study. Similarly, at 48 hrs. after drip irrigation as indicated in Table ,soil moisture content showed progressive decrease in moisture content both horizontally and vertically from the emitter location but slightly lower moisture percentage was noticed 48 hrs. after drip irrigation compared to 24 hrs. after drip irrigation. The same trend of soil moisture distribution was observed during both years of investigation.

The results of present investigation indicates that uniform soil moisture distribution due to increased frequency of irrigation at once in two days led to higher and constant moisture availability nearer to field capacity. The slow and frequent application of predetermined rate of water application could provide constant soil moisture availability to the crop in drip fertigation. Data on soil moisture content showed that in general, the moisture content was higher in soil layer of 0-30 cm vertically and it decreased with the increase in lateral distance from the emitter.

Similarly it was higher in the surface layer (0-15 cm) and followed a decreasing trend with increase in depth (Fig a.). This uniform soil water distribution represented soil water nearing field capacity. This indicated optimum soil moisture availability conditions for the crop. It implies that drip system could maintain an ideal moisture regime for optimum crop growth condition and thus ensures water saving. The crop was irrigated with drip and experienced full irrigation without any stress period, due to which roots extracted adequate moisture and nutrients efficiently without any leaching loss. This might have increased the crop growth as well as yield of the crop. Similar results in respect of soil moisture distribution have been reported by Suganya *et al*[12]., and Gokila[4] in drip irrigation.

Table 1: Soil moisture distribution (%) at 100 per cent pan evaporation in cotton

Vertical Depth from soil surface (cm)	Horizontal distance from emitter (cm)	Soil moisture distribution 24 hrs after drip irrigation (%)		Soil moisture distribution 48 hrs after drip irrigation (%)	
		2011-12	2012-13	2011-12	2012-13
0-15	0	32.9	32.7	30.9	30.8
	15	30.7	30.5	29.1	29.6
	30	28.4	28.3	26.2	26.1
15-30	0	31.1	31.1	29.2	29.1
	15	29.9	29.8	28.2	28.4
	30	28.1	28.0	26.0	25.9
30-45	0	29.5	29.6	27.7	27.5
	15	28.3	28.2	26.6	26.3
	30	26.1	26.4	25.3	25.4

Effect of drip fertigation on nutrient dynamics in soil

i. **Available nitrogen dynamics under fertigation**

The available nitrogen under fertigation levels showed increased concentrations as per the increment in the fertilizers doses from 50 to 125 per cent applied through fertigation as indicated in Table 2 and graphically depicted in Fig. B (i and ii). The available N at 50 per cent level of fertigation was comparatively more in the top layer at the dripper point and decreased horizontally upto 30 cm from dripper. Similarly, the available N slightly decreases as the depth increases from top layer (0-15 cm) to bottom layer (30-45 cm) as indicated in Table 2.However N concentration increased at 30 cm horizontal distance as the vertical depth increased. At 75 and 100 per cent fertigation of RDNK ha^{-1} also the same trend of decrease in available N from dripper point both horizontally and vertically was observed. At 125 per cent fertigation level, the available N was (234.9 and 239.5 kg ha^{-1} during 2011-12 and 2012-13 respectively) at dripper point and reduced horizontally upto 30 cm in bottom layer of 30-45 cm depth. The similar trend was observed during both the years of study in respect of available nitrogen under different levels of fertigation. The mobility of nutrients was well proven under drip fertigation system. An understanding of such transformation on nutrient mobility is very important in elucidating the soil fertility interactions. The recommended level of N and K was fertigated through urea and muriate of potash in the present study. The available N from the urea application decrease progressively from top layer and the increasing distance from the dripper point horizontally upto 30 cm. The top layer showed the higher value of 202.8, 213.7, 230.9, and 234.9 kg ha^{-1} at the dripper point while it was 200.2, 208.6,228.2,233 kg ha^{-1} in the bottom layer

(30-45 cm) below the dripper during first year of study.

The nitrogen concentration 30 cm away from emitter increased as the vertical depth increased from 0-15 cm to 30-45 cm and then concentration was in the increasing trend at 30 cm horizontal distance at all the vertical depth and it was higher at 30-45 cm vertical depth. Urea is relatively mobile in soil and it is not strongly absorbed by soil colloids. It tends to be more evenly distributed down the soil profile below the emitter and had moved laterally in the profile to 15 cm radius from the emitter. The more availability of N in the soil near the emitter is the result of adequate quantum of water available just beneath the drippers, which increased the nitrogen availability. These results are in accordance with the results of Bangar and Chaudhari[2], Gokila[4] and Pawar *et al*[10].

ii. Available potassium dynamics under fertigation

The data on available potassium as influenced by different treatments are presented in Table 3 and graphically illustrated in Fig.C (i and ii) The potassium distribution below the emitter showed progressive increased concentration as per the increment in the fertigation from 50 per cent to 125 per cent levels of fertigation and the availability of K decreased at vertical depth from 0-15 cm to 30-45 cm and also decreased as the horizontal distance was increased from emitter from 0-30 cm. Maximum K distribution was observed at 125 per cent fertigation level during both the years of study. The level of soil solution K will depends upon equilibrium and kinetic reactions that occur between different forms of soil potassium, the soil moisture content and concentration of bivalent cations in solution and exchange phage Potassium is less mobile than nitrate, but distribution in the wetted volume may be uniform due to interactions with binding sites[5]. After the fertigation the highest K concentration was found in 0-15 cm soil depth than at the lower layer i.e.15-30 cm and 30-45 cm depth. The peak quantity of K was recorded in 0-15 cm depth under the emitter .

In the present study, soil available K content was higher in the surface soil than in the sub soil. This might be due to the majority of applied K was held up in the surface soil besides lesser downward movement. Slower downward movement of applied K may be partially attributed to net upward flux of soil water in the soil profile as a result of high evapotranspiration. Mmolawa and Or[7] also reported that potassium (K) distribution in the soil profile is characterized by decreasing soil K content with depth. Suganya *et al*[12]., inferred that the available K content was higher in the surface layer due to entrance of K ions in soil exchange complex resulting in very small movement to depth layer. Gokila[4] and Pawar *et al*[10]., also reported the maximum K availability at 125 per cent fertigation and decreased K availability with decreasing level of fertigation and also reported the availability of more K near the upper surface than the deeper soil layer.

iii. Available nutrients (N and K) under soil application method

The data on available N and K as affected by soil application method are presented in Table 4 revealed that in soil application of 100 per cent RDNK ha^{-1}, the availability of N and K was decreased as the depth increased from 0-15 cm to 30-45 cm. The availability of N and K was less than all the fertigation treatments during both the years of investigation. The availability of low N and K might be due to leaching and volatilization losses of nutrients when applied by conventional method and the fertilizers may spread far away from the active root zone of crop. The decrease in available N concentration might be due volatilization losses and trapping of $NH4^+$ ion in clay crystal micelle. However, depletion in available K might be due to its fixation.

Table 2: Available –N (kg ha^{-1}) distribution in soil as affected by fertigation treatments in cotton (2011-12 and 2012-13)

Depth (cm)	Horizontal distance (cm)	2011-12				2012-13			
		T2 (50% RDNK fertigation)	T3 (75% RDNK fertigation)	T4 (100% RDNK fertigation)	T5 (125% RDNK fertigation)	T2 (50% RDNK fertigation)	T3 (75% RDNK fertigation)	T4 (100% RDNK fertigation)	T5 (125% RDNK fertigation)
0-15	**0**	202.8	213.7	230.9	234.9	205.8	217.9	235.7	239.5
	15	201.2	211.6	229.7	234.4	205.1	215.8	234.8	239.4
	30	196.3	204.1	225.6	229.8	199.3	208.3	230.0	236.8
15-30	**0**	201.2	212.4	230.4	234.1	205.6	216.6	235.5	239.1
	15	200.6	210.3	229.4	233.9	201.3	214.5	234.6	238.7
	30	198.5	206.8	227.7	231.1	202.4	210.8	232.8	237.7
30-45	**0**	200.6	210.4	230.0	233.7	203.5	214.6	235.0	238.5
	15	199.8	209.2	229.1	233.3	202.3	213.4	234.1	237.5
	30	200.2	208.6	228.2	233.0	202.1	212.6	233.9	238.9

Table 3: Available –K (kg ha^{-1}) distribution in soil as affected by fertigation treatments in cotton (2011-12 and 2012-13)

Depth (cm)	Horizontal distance (cm)	2011-12				2012-13			
		T2 (50% RDNK fertigation)	T3 (75% RDNK fertigation)	T4 (100% RDNK fertigation)	T5 (125% RDNK fertigation)	T2 (50% RDNK fertigation)	T3 (75% RDNK fertigation)	T4 (100% RDNK fertigation)	T5 (125% RDNK fertigation)
0-15	**0**	371.2	378.1	385.4	393.0	377.2	385.2	393.55	400.4
	15	367.8	374.8	381.2	388.6	373.8	381.9	389.35	396.0
	30	365.5	370.9	379.6	386.7	371.5	378.0	387.75	394.1
15-30	**0**	368.6	375.6	383.7	390.8	374.6	382.7	391.85	398.2
	15	364.4	373.8	379.3	387.0	370.4	380.9	387.45	394.4
	30	361.7	370.0	376.8	383.8	367.7	377.1	384.95	391.2
30-45	**0**	366.5	374.3	380.1	387.8	372.5	381.4	388.25	395.2
	15	361.8	371.9	376.7	383.6	367.8	379.0	384.85	391.0
	30	360.5	367.6	373.3	380.3	366.5	374.7	381.45	387.7

Table 4: Available nitrogen and potassium (kgha^{-1}) distribution in soil under soil application of fertilizers through drip irrigation (T_1)

Depth (cm)	2011-12		2012-13	
	Nitrogen	Potassium	Nitrogen	Potassium
0-15	194.9	362.2	197.2	372.8
15-30	190.4	356.5	193.6	368.9
30-45	186.2	354.9	188.2	368.2

Seed cotton yield of Bt Cotton

Drip fertigation levels had marked and favourable influence on seed cotton yield due to various treatments.(Table 5). Drip fertigation at 125 per cent RDNK ha^{-1} has recorded significantly higher seed cotton yield (3680 kg ha^{-1} and 3326 kg ha^{-1}) during 2011-12 and 2012-13 respectively and followed by drip fertigation at 100 per cent RDNK ha^{-1} which registered next higher seed cotton yield of 3362 kg ha^{-1} and 3030 kg ha^{-1} respectively during first and second year of study. There was a significant response to fertigation of 125 per cent RDNKha^{-1} through drip in five splits than other lower level of fertigation (50,75 and 100 per cent).Drip fertigation at 75 per cent RDNK ha^{-1} registered significantly comparable yield with 100 per cent RDNK ha^{-1} applied through soil by conventional method during both the years of study and pooled of two years also show the similar trend indicating 25 per cent fertilizer saving through fertigation when compared to conventional method of fertilizer application. 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 Bharambe *et al*[3]., Kadam[5] and Pawar *et al*[10]. 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.

Table 5: Seed cotton yield (kg ha^{-1}) as influenced by different treatments in cotton

Treatments	Seed cotton yield (kg ha^{-1})		
	2011-12	2012-13	Pooled
T_1: DI +100% RDNK soil application	2740	2519	2629
T_2: DF+ 50% RDNK	2350	2212	2281
T_3: DF+ 75 % RDNK	2894	2620	2757
T_4: DF+ 100 % RDNK	3362	3030	3196
T_5: DF+ 125 % RDNK	3680	3326	3503
S. E. (m) ±	102	95	93
C. D. at 5%	315	294	287
GM	3005	2742	2874

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*[8]., Singh *et al*[11]., and Ayyadurai *et al*[1]., also reported that drip fertigation had greater advantages and increased seed cotton yield as compared to broadcast application of fertilizer nutrients.

CONCLUSIONS

On the basis of two years data, it could be concluded that application of 100 per cent recommended dose of N and K in five splits (P as basal) found to be best for maximizing the yield and beneficial in increasing the seed cotton yield and better movement of nitrogen and potassium nutrients under split application of nutrients through drip irrigation.

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