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Effect of crop geometries and fertility levels on growth, yield and residual nutrients of cotton (*Gossypium hirsutum*) hybrids under rainfed condition*

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The cotton (*Gossypium hirsutum* L.) plant is unique because it is a perennial with an indeterminate growth habit. Associated with this complex growth habit is an extreme sensitivity to adverse environmental conditions and crop managements. Amongst crop management options, crop geometries, hybrids and fertilizers levels are major parts of crop cultivation that visualized now than ever before for quality fibre production. Of which, fertilizer levels and plant populations are most important (Ali *et al.* 2009). Balanced fertilization and crop geometries has been proved to be kingpin in agricultural production under rainfed condition and contributed to nearly 50% of overall increase in production systems (Kumari *et al,* 2008). Impact of nitrogen (N) and potassium (K) fertilization on yield and yield components are well documented, but their combined effects on cotton are poorly understood. N or K application increased lint yield, and a combination of high plant density, N and K application further improved lint yield in the lower fertility levels, while only K application increased lint yield in the higher fertility level (Dong *et al*. 2010).

However, cotton hybrids require tailored crop geometry and fertilization for yield maximization under rainfed condition. Cotton, particularly hybrids being exhaustive, draw plenty of soil nutrients and thus under continuous cropping pattern nutrient management assumes importance. Nutrient recommendation varies with crop response, soil condition and the cropping system followed (Cheng-Song *et al.* 2010). It is substantially required to fully exploit the production potential of hybrids by standardizing some of the agronomic practices particularly optimum crop geometry concurrent with NPK fertilization that influence the growth, development and quality parameter of cotton, because of adequate crop geometry prevents inter-plant competition for resources. It was observed that each unit increase in fertility level of 60-30-15, 80-40-20 and 100-50-25 N-P-K kg/ha significantly increased plant height, leaf area index, dry matter, yield attributes and yield (Sisodia and Khamparia 2007). Although, balanced application of NPK maintain physiological, bio-chemical and metabolically process of plant to produce good quality fibre of cotton and sustained productivity of soil. Hence, there is a need to refine/modify the crop geometry and nutrient need in this hi-tech cotton hybrid (Sankaranarayanan *et al.* 2011) to realize its full yield potential, a field trial was carried out to study the effect of crop geometries and fertility levels on growth, yield and residual nutrients of cotton hybrids under rainfed condition.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) season of 2008-2009 at Cotton Research Unit, Central Research Station, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola at 22°42' N latitude and 77°02' E longitude and at an altitude of 307.42 meters above mean sea level in the Vidarbha region of Maharashtra to study the effect of crop geometries and fertility levels on growth, yield and residual nutrients of cotton hybrids under rainfed condition. The total rainfall recieved during crop season was 429.1 mm. The soil of experimental plot was medium black having clayey textural class (61.5% clay, 24.2% silt and 14.3% sand) with low in organic carbon (0.39%), and available N (193.6 kg/ha), medium in P_2O_5 (14.2 kg/ha), but high in K_2O (492.0 kg/ha). The pH and EC (dS/m) of soil was 7.97 and 0.362, respectively. The climatic condition of Akola is semi-arid and characterized by three distinct seasons, viz. hot and dry summer (March to May), warm and rainy monsoon (June to October) and mild cold winter (November to February).

The experiment was conducted in split-plot design

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replicated in triplicate. The main plot assigned with two crop geometry (S_1-90 × 60 cm and S_2 -60 × 60 cm) and three cotton hybrids (V_1-MLCH-318, V_2-VBCH-2231 and V_3-PKV Hy-2). In sub-plot treatments, three fertility levels of NPK (F_1-37.5: 18.75: 18.75, F_2-50: 25: 25 and F_3-62.5: 31.25: 31.25 kg N: P: K/ha). The source of N, P and K were urea, single super phosphate and muriate of potash, respectively. The crop was fertilized with different levels of N, P and K as per the treatments. N as per treatments was applied in two equal splits, i e half at sowing and remaining half at 60-65 days after emergence (square stage). Full dose of P and K was given to all the plots at sowing as per treatments. The sowing was done by dibbling of 2-3 seeds at each hill with seed rate of 4.5 kg/ha (Hybrids). The plant population was maintained by gap filling at initial stage (within a week of germination) and subsequent thinning keeping single plant/hill. Two hoeing and two hand weeding were done to keep crop-weed free and conserve soil moisture. The spray of monocrotophos and endosulphan (35 EC) plus copper sulphate (Katore *et al.* 2006) were applied twice, i e firstly at early vegetative stage and secondly at boll formation stage) to protect crop from sucking pest. Data of growth attributes, viz. plant population (at initial and harvest), plant height (cm), no. of functional leaves/plant, dry matter accumulation (g/plant) and leaf area (dm^2/plant), whereas yield and yield attributing characters, viz. no. of monopodial and sympodial branches, seed cotton weight/plant(g), lint yield, seed cotton yield and stalk yield (kg/ha) were recorded. The leaf area was measured using automatic leaf area meter (Model LI-COR 3100). Lint yield (kg/ha) was calculated by ginning percentage multiply with seed cotton yield (kg/ha) and divided by 100. The residual N, residual P and residual K in soil were determined as per standard procedure. All the data were statistically analyzed to draw a valid conclusion (Gomez and Gomez 1984).

Growth attributes

Initial (at emergence) and final plant stand (at harvest) was significantly influenced by different crop geometry (Table 1). Crop geometry of 60 cm × 60 cm (S_2) recorded significantly higher plant population (271.51 '00'/ha and 242.77 '00'/ha) than that of 90 cm × 60 cm (177.47 '00'/ha and 149.89 '00'/ha) (S_1) at initial and final stage, respectively. The effect of hybrids and different levels of NPK fertilization on initial and final count was not significant. Crop geometry were significantly influenced the growth parameters, viz. plant height, number of functional leaves, dry matter accumulation and leaf area (Table 1). Crop geometry of 90 cm × 60 cm (S_1) recorded significantly the highest plant height (67.70 cm), number of functional leaves, i e capable of photosynthesizing assimilates (68.43 leaves), dry matter accumulation (52.81 g), leaf area/plant (38.46 dm^2). The functional leaves are that which is capable of photosynthesizing and form assimilates during crop cycle. This is might be due to less

Table 1 Growth, yield attributes and yield of cotton as influenced by crop geometry, varieties and fertility levels

Treatment	Plant population		Plant height (cm)	Leaves/ plant	Dry matter (g/plant)	Leaf area (dm^2)/ plant	Monopo-dial branch/ plant	Sympo-dial branch/ (g/plant)	Seed cotton weight	Lint yield (kg/ha) (kg/ha)	Seed cotton yield (kg/ha)	Cotton stalk yield (kg/ha)
	Initial stand '00'/ha	Final stand '00' /ha										
Crop geometry												
S_1 - 90 cm × 60 cm	177.47	149.89	62.33	68.43	52.81	36.92	2.85	13.76	38.22	301	772	781
S_2 - 60 cm × 60 cm	271.52	242.77	67.70	59.50	44.63	34.74	2.22	16.36	33.28	345	910	1058
CD (*P*=0.05)	8.36	9.50	2.77	4.29	1.62	2.04	0.26	0.95	2.88	34.04	84.03	76.15
Hybrids												
V_1–MLCH 318	226.60	201.47	70.33	73.91	53.30	39.56	2.91	16.78	42.07	407	1034	1054
V_2-VBCH 2231	221.83	188.18	58.72	57.82	42.02	31.95	2.11	13.06	27.94	235	628	762
V_3 –PKV Hy-2	225.05	199.33	66.00	60.16	50.85	35.98	2.58	15.35	37.23	329	861	942
CD (*P*=0.05)	NS	NS	3.39	5.25	1.98	2.50	0.32	1.17	3.53	41.34	102.04	96.03
Fertility level (kg N:P: K/ ha)												
F_1–37.5+18.75 + 18.75	219.32	191.18	60.55	56.07	46.53	32.70	2.20	13.67	31.52	247	736	834
F_2 –50 + 25 + 25	225.26	196.76	65.77	64.70	48.78	36.33	2.50	14.88	36.01	330	815	935
F_3-62.5+31.25 + 31.25	228.91	201.04	68.72	71.12	50.86	38.46	2.91	17.13	39.72	3.93	972	988
CD (*P*=0.05)	NS	NS	2.76	3.01	1.74	2.12	0.18	1.20	1.58	45.23	92.11	50.02

plant density under wider geometry of 90 cm × 60 cm (S_1), which utilized more solar energy, moisture and nutrient efficiently as compared to closer geometry of 60 cm × 60 cm (S_2). These results are in close conformity with findings of Sisodia and Khamparia (2007).

All the growth characters were significantly influenced by different hybrids (Table 1). It was observed that MLCH 318 (V_1) recorded significantly taller plant (70.33 cm) with highest number of functional leaves (73.91), dry matter accumulation (53.30 g) and leaf area/plant (39.56 dm^2) over PKV Hy-2 (V_3) and VBCH 2231 (V_2). This is might be due to the dwarf nature and poor tolerability of water stress by VBCH 2231 which leads to produce fewer growth characters under rainfed condition as compared to MLCH 318 and PKV Hy-2.

The successive increase in the fertility levels significantly improved the plant height, number of functional leaf, dry matter accumulation and leaf area (Table 1). The data has indicated that, the application of 62.5:31.25:31.25 kg N:P:K/ha significantly recorded tallest plant (68.72 cm) with maximum number of functional leaf (71.12), dry matter accumulation (50.86 g) and leaf area/plant (38.46 dm^2) over the treatment of 37.5: 18.75: 18.75 and 50: 25: 25 kg N: P: K/ha. Nutrient, particularly macronutrient enhance plant growth by participating in cell division and cell elongation of plants leads to better growth and development. These results are corroborated with the findings of Sisodia and Khamparia (2007).

Yield and yield attributes

Yield and yield attributes significantly influenced by crop geometry and fertility levels (Table 1). Closer crop geometry of 60 cm × 60 cm (S_2) produced significantly the highest number of sympodial branches/ plant (16.36), lint yield (345 kg/ha), seed cotton yield (910 kg/ha) and stalk yield (1058 kg/ha) over wider crop geometry of 90 cm × 60 cm (S_1). Under closer crop geometry, plant grow taller in respect of vertical space and produces highest no. of sympodial branches and cotton bolls/plant due to more accommodation of plants/unit area resulted in higher lint and seed cotton yield over wider crop geometry. These findings are parallel with earlier findings of Ali *et al.* (2009a). Whereas, 90 cm × 60 cm (S_1) crop geometry recorded highest no. of monopodial branches (2.85) and seed cotton weight/plant (38.22 g). It was mainly due to the more availability of wider space and photosynthates to individual plant in contrast to closer crop geometry. Siddiqui *et al.* (2007) who stated that increase in density (spacing) decreases number of sympodial branch/plant, but increase in monopodial branch/plant.

Cotton hybrids, MLCH 318 (V_1) recorded significantly the highest number of monopodial branches (2.91), sympodial branches (16.78), seed cotton weight/plant (42.07 g), lint yield (407 kg/ha), seed cotton yield (1 034 kg/ha) and stalk yield (1 054 kg/ha) over VBCH 2231 (V_2) and PKV Hy-2 (V_3). It was mainly due to the magnitudes production of yield attributing characters like fruiting body (sympodia), cotton bolls and seed cotton weight/plant by MLCH 318 results highest yield in terms of lint, seed cotton and stalk yield.

It was observed that the yield and yield characters increased significantly with increased in fertility levels (Table 1). With the application of 62.5: 31.25: 31.25 kg N: P: K/ha recorded significantly the highest number of monopodial branches (2.91), sympodial branches (17.13), seed cotton weight/plant (39.72 g), lint yield (393 kg/ha), seed cotton yield (972 kg/ha) and stalk yield (988 kg/ha) over the application of 37.5: 18.75: 18.75 and 50: 25: 25 kg N: P: K/ha. On an average, increase in lint yield; 16.03 and 37.15% while seed cotton yield; 16.15 and 24.27% over the application of 50: 25: 25 and 37.5: 18.75: 18.75 kg N: P: K/ ha. The significant increase in seed cotton, lint and stalk yield were largely a function of improved growth and the consequent increased in different yield components due to adequate supply of major nutrient under successive increase in fertility levels which finally resulted in higher yield of cotton. This is might be possible due to continuous and balanced supply of nutrients, enhancing their availability to plant under higher fertility levels of 62.5: 31.25: 31.25 kg N: P: K/ha (Anonymous 2008). Similar results also reported by Girma *et al.* (2007)

Residual nutrient status of soil

Significantly higher residual N (204.00 kg/ha), P (16.67 kg/ha) and K (489.04 kg/ha) status of soil after harvest was recorded with crop geometry of 90 cm × 60 cm (S_1) as compared to crop geometry of 60 cm × 60 cm (S_2) (Table 2). It was mainly due to less plant density under wider crop geometry of 90 cm × 60 cm (S_1) as compared to high plant density under 60 cm × 60 cm. The finding is in close conformity with the findings of Kalaichelvi (2008). Among hybrids, VBCH 2231 (V_2) recorded significantly higher residual nitrogen (200.44 kg/ha), P (16.82 kg/ha)

Table 2 Residual N, P and K (kg/ha) status in soil after harvest as influenced by different treatments

Treatment	Residual N (kg/ha)	Residual P (kg/ha)	Residual K (kg/ha)
Crop geometry			
S_1–90 cm × 60 cm	204.00	16.67	489.04
S_2–60 cm × 60 cm	186.02	14.96	481.42
CD (P=0.05)	4.86	0.77	6.95
Hybrid			
V_1– MLCH 318	191.54	14.76	480.09
V_2–VBCH 2231	200.44	16.82	496.50
V_3–PKV Hy-2	193.04	15.86	488.03
CD (P=0.05)	5.96	0.95	7.36
Fertility level (kg N:P: K/ha)			
F_1–37.5 + 18.75 + 18.75	185.08	14.52	480.23
F_2–50 + 25 + 25	195.83	15.69	488.63
F_3–62.5 + 31.25 + 31.25	204.11	17.24	495.26
CD (P=0.05)	7.08	1.28	6.63
Initial status	193.6	14.2	492.0

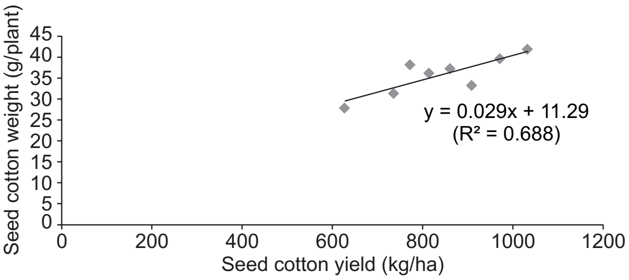

Fig 1 Regression between seed cotton weight (g/plant) and seed cotton yield (kg/ha)

and K (496.50 kg/ha) status of soil over MLCH 318 (V_1) and PKV Hy-2. It was mainly less uptake of nutrient by VBCH 2231 from the soil.

The residual N, P and K status of soil (kg/ha) after harvest was increased significantly with each increased levels of NPK fertilization (Table 2). An application of 62.5: 31.25: 31.25 kg N: P: K/ha resulted in significantly the highest residual N (204.11), P (17.24) and K (495.26 kg/ha) status of soil as compared to the fertility level of 37.5: 18.75: 18.75 and 50: 25: 25 kg N: P: K/ha. Increase in available P might be due to decomposition of organic matter and also phosphorus solubilization from the native soil pool. Higher availability of K could be ascribed to addition of potassium to available pool of the soil. Similar findings are associated with the findings of Dong *et al*. (2010)

The seed cotton yield and seed cotton weight/plant was positively correlated with correlation co-efficient of 0.688. This was further supported by the regression analysis. Thus unit increased in seed cotton weight (g/plant) caused increase in seed cotton yield by 11.29 kg/ha (Fig 1). The increases in seed cotton yield with increase in seed cotton weight/ plant was also reported by Singh and Narkhede (2010).

SUMMARY

A field experiment was conducted during *kharif* season of 2008-09 to study the effect of crop geometries and fertility levels on growth, yield and residual nutrients of cotton (*Gossypium hirsutum* L.) hybrids under rainfed condition. Cotton hybrids MLCH 318 was planted under wider crop geometry of 90 cm × 60 cm which recorded significantly higher growth parameters, monopodial branches and seed cotton weight/plant. However, yield potential of MLCH 318 were higher under closer crop geometry (60 cm × 60 cm) and recorded significantly taller plant, yield attributes and yield of cotton over wider crop geometry of 90 cm × 60 cm (S_1) due to more number of plants stand at initial and harvest stages, respectively. Although, cultivar VBCH 2231 (V_2) with crop geometry of 90 cm × 60 cm (S_1) recorded more in residual status of N (200.44 and 204 kg/ha), P (16.82 and 16.67 kg/ha) and K (496.50 and 489.04 kg/ha), respectively. Among fertility levels, growth characters, yield attributes and yield of cotton with residual N (204.11), P (17.24) and K (495.26 kg/ha) were significantly higher under highest levels of fertility, i.e. 62.5: 31.25: 31.25 kg N: P: K/ha. Thus, it concluded that sowing of cultivar MLCH 318 at crop geometry of 60 cm × 60 cm and fertilized with. 62.5: 31.25: 31.25 kg N: P: K/ha produced significantly higher yield attributes and yield under rainfed condition.

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