Journal of Applied and Natural Science 8 (4): 2070-2076 (2016)

Modified planting geometry and fertilizer rate on productivity of corn (*Zea mays* L.) in *Vertisols*

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Received: March 7, 2016; Revised received: August 8, 2016; Accepted: November 9, 2016

Abstract: A field experiment was conducted at Raichur, Karnataka with an objective to find out production potential of grain corn planted in clumps and rate of fertilizer application. Design followed was split plot and repeated thrice with rate of fertilizer application as main factor and planting geometry as sub factor. Treatments consists of planting corn at 2, 3, 4 seeds/hill compared with single seeds/hill (60 cm x 20 cm) and farmers practice uneven spacing. In clumped plants inter row spacing is similar (60 cm) and intra row distance is differ to maintain uniform plant density (83,333 plants/ha) in each treatment. Recommended dose of fertilizers (RDF) was applied in 2 splits and 150% RDF in 3 splits. Results revealed that planting 2 seeds /hill at 60 cm x 40 cm recorded significantly higher yield, economics of corn as compared to 3 and 4 seeds/hill and farmers practice. As increased plant population per hill maintains higher soil moisture at 75 days after planting (7.5-9.4%) and lower dry matter per plant at harvest (236.3 to 185.5 g) as compared to conventional planting. Application of higher (150%) fertilizers in 3 splits recorded higher dry matter production, grain yield, and economic returns over RDF. This may be useful strategy for corn productivity enhancement by clump planting with higher fertilizer rate.

Keywords: Clump planting, Corn, Planting geometry, Soil moisture

INTRODUCTION

Corn is known for its versatility for nutrients and soil moisture. Potential crop yield can be harnessed by providing sufficient soil moisture and adequate nutrient supply. Under rainfed ecosystem the primary management practices that scientists and farmers tried to conserve stored soil water for use during the later growth stages. Grain corn is a major crop grown in different parts of India and Karnataka as well. Crop would be sown in all three seasons under rainfed as well as protective irrigation. Its productivity is much lower than national and world average. Blumenthal and Naveh (1976) reported that under dryland conditions corn grain yield increased 353 kg ha^{-1} with increasing plant population from 17300 plants ha^{-1} to 27200 plants ha^{-1} but increase of population beyond 27200 resulted in inconsistent grain yields. Under dryland conditions, row width and available soil water influence the corn productivity (Mohankumar Kapanigowda *et al.,* 2010). Narrow spacing, increased shading, reduce evapotranspiration and increase the competition between plants for light and water in the crop canopy. Andrade *et al.* (2002) from Argentina reported that increase in the maize grain yields by reducing the row spacing from 0.7 m to 0.52 m due to increase in radiation interception and decrease in plant to plant competition for available water, nutrient and light. Water stress during booting and flowering stages resulted in sorghum grain yield reduction up to 85%. Many agronomic strategies such as skip row configurations, different spacing, reduced plant populations, reduce crowding stress, mulching, and conservation agriculture have been tested to conserve soil moisture later in growing season (Noorwood, 2001). Whereas, Bandaru *et al.* (2006) and Krishnareddy *et al.* (2010) opined that planting grain sorghum in clumps rather than spaced uniformly conserves soil water use until later in the season and may enhance grain yield. Results also indicated early blooming, reduced leaf area development and tiller number per unit area. These are useful strategies for successful corn to grown under deficit soil moisture. Keeping these facts, field investigation was conducted in *Vertisols* with an objective to enhance maize productivity by altering geometry, and fertilizer rate when grown in clumps.

MATERIALS AND METHODS

Site description: Experiment was conducted at Main Agricultural Research Station, Raichur (16^{o}32 N, 77^{o}12E, 363m) during *Kharif* 2012. A soil of the experiment site was red sandy loam with pH 6.5. The available soil nitrogen and phosphorus was in medium and higher in available soil potassium Experiment was laid out in split plot design with three replications. Main plot treatment consists of fertilizer application rate at 100-50-25 kg N-P-K/ha and 150-75-37.5 kg N-P-K/ha. Sub plot treatments consists of six planting geometry *viz*., 60 cm x 20 cm (G_1) (1 seed/hill), 60 cm x 40 cm (G_2) (2 seeds/hill), 60 cm x 60 cm (G_3) (3 seeds/hill) and 60 cm x 80 cm (G_4) (4 seeds/hill). These are compared with paired row (G_5) and farmers practice (G_6) of uneven spacing. The inter row spacing in all the sub plot treatment were maintained at 60 cm and inter plant spacing was according to treatments. In all the treatments plant population was maintained at 83,333 per ha except farmers practice of uneven spacing.

Both incoming and outgoing photosynthetically active radiation (PAR) values were measured periodically at the top and bottom of the corn crop canopy and leaf area index throughout the season by using ceptometer (CI-100, USA). The above measurements were taken at regular intervals on clear sunny days between 11:00and 14:00 h IST when solar zenith angle were minimum. The intercepted photosynthetically active radiation (IPAR) for a particular day was computed as the difference between PAR at the top and bottom of canopy. The fraction of IPAR (fIPAR) for a particular day is the ratio between intercepted PAR and total incident PAR on that day (Jha *et al.,* 2012). Values for fIPAR for each day after sowing were interpolated between actual measurements by linear interpolation throughout the crop season. Daily incoming solar radiation was calculated by the procedure described in Allen *et al.* (1998) using daily bright sunshine hours observation. The daily incoming solar radiation was multiplied by a factor 0.48 to get incoming incident PAR (Fig.2). Then the daily incident PAR values were multiplied by corresponding daily fIPAR values to compute daily intercepted PAR (IPAR). For computing above ground biomass plants are harvested in 1m row length and converted into hectare basis. Soil moisture at 0-15 cm depth was estimated by gravimetric at 45 and 75 days after planting. Grain and straw yield of corn per hectare was estimated by harvesting plants from net area of 18.24 m^2. Economics was worked out by considering output and prevailing market price.

Statistical analysis: The data were statistically analyzed using analysis of variance (ANOVA) as applicable to split plot design (Gomez and Gomez, 1984). The significance of the treatment effects was determined using F-test, and the difference between the means was estimated using least significance difference and Duncan's multiple range tests at 5% probability level. Regression analyses were performed using the data analysis tool pack of Sigma Plot 11 version.

RESULTS AND DISCUSSION

Weather condition: The meteorological data prevailed during the period and mean of 32 years was recorded at meteorological station located 500 m away from the experimental site are presented in Fig. 1. The average normal annual rainfall for the experimental site was 628 mm of which highest in June (113 mm) and September months (180 mm). The average number of rainy days of the locations is 67 days in a year. An amount of 425 mm rainfall received during crop growth period shortage of 19 per cent over the normal. Incident solar radiation is calculated as per FAO 56 manual (Allen *et al.,* 1998) and date is presented in Fig.2.

The annual average maximum and minimum air temperature were 39.9^{o}C and 16^{o}C in April and December months respectively (Fig.1). April and May months were the hottest, while December and January were the coolest months. During the season (*Kharif*) the maximum air temperature ranged between 31.1 and 36.2^{o}C and minimum air temperature between 15.6^{o}C and 23.8^{o}C which were very ideal for corn. In general, atmospheric temperature, relative humidity sunshine hours and rainfall distribution recorded during *Kharif* 2012 was better suited to corn.

Growth attributes: Growth attributes of corn was significantly influenced by fertilizer application rates and planting geometry. Plant height of corn was signif-

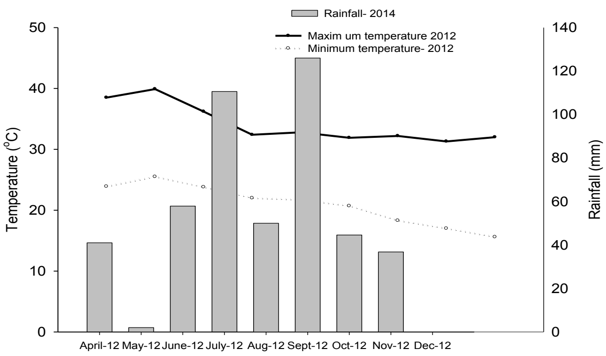

Fig. 1. *Rainfall and temperature prevailed in experimental site during cropping period 2012.*

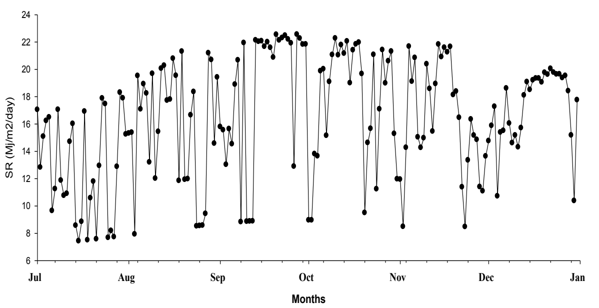

Fig. 2. *Incident solar radiation MJ/m^2 recorded during different months of cropping period.*

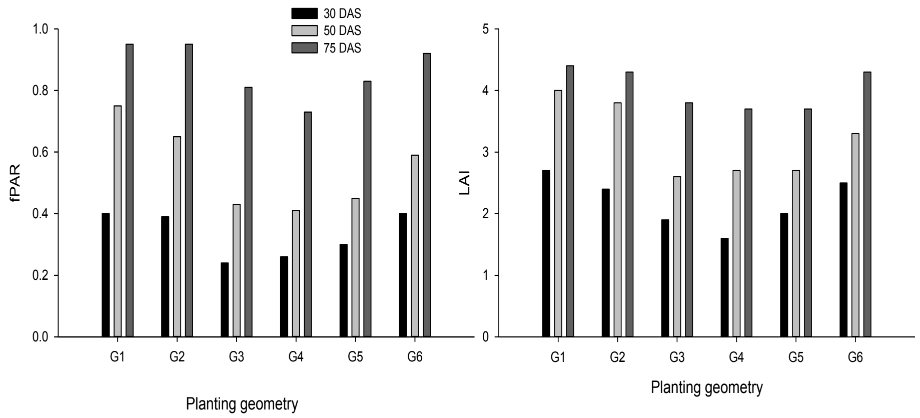

Fig. 3. *Leaf area index and fraction of PAR (%) as influenced by modified planting geometry and fertilizer application.. G_1: Recommended planting 60 x 20 cm (83,333 plants/ha); G_2: Clump planting 2 seeds per hill 60 x 40 cm spacing (83,333 plants/ ha); G_3: Clump planting 3 seeds per hill 60 x 60 cm spacing (83,333 plants/ha); G_4: Clump planting 4 seeds per hill 60 x 80 cm spacing (83,333 plants/ha); G_5: Paired row of planting 1 seed per hill 45-90-45x 20; G_6: Farmers practice uneven spacing.*

icantly influenced by fertilizer application levels and planting pattern. Taller corn plants were noticed through out the crop growth period with application of 150 per cent RDF over blanket recommendation. Among planting patterns taller plants of corn were noticed in one seed per hill in uneven and 60 x 20 cm spacings. Shortest plants were recorded four seed hill planted at 60 x 80 cm spacing. Supply of graded levels of fertilizers to closer spaced plants has resulted in taller plants as compared to wider spaced seeds planted in clumps.

Fraction of PAR (%): Radiation interception (RI) is a percentage of solar radiation reaches to ground surface and available for plant growth. Higher the values of IPAR lower the quantity of solar radiation reaches to below the crop canopy. At early stage of crop growth lower IPAR indicate plant canopy spread is lower and light utilization at minimum. As growth advances, the IPAR also increases at critical leaf area index the values become plateau. It changes at different growth stages as influenced by fertilizer application rate and planting geometry (Fig.3). Significantly higher fIPAR was recorded at 45 and 75 days after sowing with application of 150% RDF as compared to recommended blanket application. Among planting geometry combinations significantly higher radiation interception was recorded in 60 x 20 cm spaced plants and farmers practice of uneven spacing. Lower IPAR was recorded in wider spaced plants at 60 x 40 cm, 60 x 60 cm and 60 x 80 cm. The results are in conformity with the findings of Krishna Reddy *et al*. (2010) and Mohankumar Kapanigowda *et al.* (2010).

Leaf area index: Leaf area index (LAI) is an indication of leaf area development and canopy coverage was significantly influenced by fertilizer application levels and planting geometry (Fig. 3). Application of graded levels of fertilizer has produced more leaves and canopy coverage (2.3, 3.4 and 4.3 LAI at 30, 50 and 75 DAS respectively). Better availability and sufficient quantity of nutrients through graded fertilizer levels may results in better growth and development of leaves as compared to lower levels.

Among planting geometry, wider spacing with increased number of seeds per hill was significantly affected LAI (Table 3). It was higher in uneven intra row spacing and 60 x 20 cm spacing. Lower LAI in wider row spaced plants indicated more space was available for plants and more radiation intercepted to ground surface. While lower LAI was recorded in recommended fertilizer application to corn plants sown at three and four seeds per hill. Maddonni, *et al.* (2006) reported that narrow rows have been shown to increase IPAR when LAI values were below the critical LAI value. A change in LAI due to clump planting was also reported in corn by Mohankumar Kapanigowda *et al*. (2010).

Dry matter production: Dry matter production per plant at different growth stages was significantly influenced by fertilizer rate and planting geometry (Table 1). It was higher by application of 225-112.5- 56.25 kg N-P-K/ha in three splits (57.7 to 235.2 g/plant) as compared to recommended blanket application (55.2 to 212.6 g/plant). Among planting geometry, higher biomass production was recorded in 60 x 20 cm planting (61.7 to 236.3 g/plant) and uneven spacing (6.6 248.8 g/plant) lower in 60 cm x 80 cm with 4 seeds per hill (47.4 to 185.5 g/plant) and 60 x 60 cm spacing with 3 seeds per hill 52.3 to 186.2 g/plant). As intra row spacing increases space, available for individual plant will also increases. However, due to competition created more seeds per hill dry matter production was decreases.

Grain and stover yield: Grain and stover yield of corn was significantly influenced by fertilizer application rates and planting geometry (Table 2). Application of 225-112.5- 56.25 kg N-P-K/ha in three splits recorded

Table 1. Above ground biomass and plant height of corn as influenced by fertilizer rate and planting geometry.

Planting geometry (G)	Above ground biomass (g/plant)									Plant height (cm) at harvest		
	50 DAS			75 DAS			At harvest					
	Fertilizer rate (F)			Fertilizer rate (F)			Fertilizer rate (F)			Fertilizer rate (F)		
	F_1	F_2	Mean	F_1	F_1	F_1	F_1	F_2	Mean	F_1	F_2	Mean
G_1	58.1	65.4	61.7	125.2	136.6	130.9	213.3	259.3	236.3	222.3	225.3	223.8
G_2	57.0	59.0	58.0	108.3	120.9	114.6	228.0	261.7	244.8	210.3	210.3	210.3
G_3	50.7	53.9	52.3	95.7	106.4	101.0	178.3	194.0	186.2	191.3	199.0	195.2
G_4	45.8	48.9	47.4	100.3	99.1	99.7	189.3	181.7	185.5	185.3	209.7	197.5
G_5	53.0	52.4	52.7	108.0	110.1	109.1	230.0	253.0	241.5	179.0	216.3	197.7
G_6	66.5	66.7	66.6	115.7	115.4	115.5	236.3	261.3	248.8	202.0	232.7	217.3
Mean	55.2	57.7		108.9	114.7		212.6	235.2		198.4	215.6	
	S.Em+	CD		S.Em±	CD		S.Em±	CD (P=0.05)		S.Em+	CD	
G	0.41	1.06		1.11	2.86		4.40	11.30		1.4	4.3	
F	0.13	0.54		0.28	1.20		0.42	1.79		1.9	4.9	
S x F	1.62	4.15		3.65	9.39		10.46	26.88		9.0	23.2	

F_1: 100% recommended NPK at 2 splits; F_2: 150 % recommended NPK at 3 splits; G_1: Recommended planting 60 x 20 cm (83,333 plants/ha); G_2: Clump planting 2 seeds per hill 60 x 40 cm spacing (83,333 plants/ha); G_3: Clump planting 3 seeds per hill 60 x 60 cm spacing (83,333 plants/ha); G_4: Clump planting 4 seeds per hill 60 x 80 cm spacing (83,333 plants/ ha); G_5: Paired row of planting 1 seed per hill 45-90-45x 20; G_6: Farmers practice uneven spacing.

Table 2. Grain and stover yield of corn as influenced by fertility levels and planting geometry.

Planting geometry (G)	Seed yield (kg/ha)			Stover yield (kg/ha)			HI		
	Fertilizer rate (F)			Fertilizer rate (F)			Fertilizer rate (F)		
	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2	Mean
G_1	3,845	4,440	4,633	6,968	6,813	6,891	0.36	0.39	0.38
G_2	4,924	5,262	5,093	6,235	6,980	6,607	0.44	0.43	0.44
G_3	4,290	4,764	4,527	4,982	4,598	4,790	0.46	0.51	0.49
G_4	4,453	4,813	3,893	4,032	4,235	4,133	0.52	0.53	0.53
G_5	4,448	4,628	4,538	5,461	4,811	5,136	0.45	0.49	0.47
G_6	4,244	4,752	4,498	5,590	6,062	5,826	0.43	0.44	0.44
Mean	4,367	4,777		5,545	5,583				
	S.Em±	CD (P=0.05)		S.Em±	CD (P=0.05)		S.Em±	CD (P=0.05)	
F	16.2	69.5		14.9	64.0		0.001	0.004	
G	127.8	328.6		113.7	292.3		0.005	0.013	
G x F	183.2	470.9		382.2	982.5		0.013	0.034	

F_1: 100% recommended NPK at 2 splits; F_2: 150 % recommended NPK at 3 splits; G_1: Recommended planting 60 x 20 cm (83,333 plants/ha): G_2: Clump planting 2 seeds per hill 60 x 40 cm spacing (83,333 plants/ha); G_3: Clump planting 3 seeds per hill 60 x 60 cm spacing (83,333 plants/ha); G_4: Clump planting 4 seeds per hill 60 x 80 cm spacing (83,333 plants/ ha); G_5: Paired row of planting 1 seed per hill 45-90-45x 20 ; G_6: Farmers practice uneven spacing.

Table 3. Interaction of fertilizer application and planting geometry on grain and stover yield per clump of corn.

Treatment	Grain yield (g/ clump)	Stover yield (g/ clump)	Clump HI
F_1G_2	128.2	192.4	0.40
F_1G_3	164.4	172.2	0.49
F_1G_4	213.7	160.9	0.57
F_2G_2	139.3	201.1	0.41
F_2G_3	171.5	165.5	0.51
F_2G_4	235.0	160.3	0.59

F_1: 100% recommended NPK at 2 splits; F_2: 150 % recommended NPK at 3 splits; G_2: Clump planting 2 seeds per hill 60 x 40 cm spacing (83,333 plants/ha); G_3: Clump planting 3 seeds per hill 60 x 60 cm spacing (83,333 plants/ha); G_4: Clump planting 4 seeds per hill 60 x 80 cm spacing (83,333 plants/ha).

higher grain yield (4777 kg/ha) over blanket application of 150-75-37.5 kg N-P-K/ha (4284 kg/ha). Application of fertilizers at higher rate enhanced grain yield of corn to the tune of 10.32 per cent over blanket dose. Graded levels of fertilizers also produced higher stover yield with an improvement of 6.5 per cent over blanket application (5084 kg/ha). Corn stalk diameter has previously been shown to decrease with increased plant density (Boomsma *et al.,* 2009; Widdicombe and Thelen, 2002).

Among planting geometric combinations significantly higher corn grain yield was recorded in 60 x 20 cm spaced plants with two seeds per hill (5262 kg/ha) compared to rest of the treatments. Significantly decreased grain yield was recorded in 60 x 80 cm spaced plants with four seeds per hill (3869 kg/ha). However, there was no significant difference among 60 x 20 cm spaced one seed/hill, 60 x 60 cm spaced with three

Table 4. Economics of corn production under varied fertilizer application and planting geometry.

Treatment	Cost of cultivation (x '000 Rs./ha)	Gross return (x '000 Rs./ha)	Net return (x '000 Rs./ha)	B: C ratio
Fertilizer levels				
F_1	29.3	80.38	51.08	1.74
F_2	33.1	88.62	55.52	1.68
Planting geometry				
G_1	31.2	88.17	56.97	1.83
G_2	31.2	95.47	64.27	2.06
G_3	31.2	83.24	52.04	1.67
G_4	31.2	71.60	40.40	1.29
G_5	31.2	83.94	52.74	1.69
G_6	31.2	84.31	53.10	1.70

Market price of Grain – Rs.16.8/kg stover Rs. 1500/t; F_1: 100% recommended NPK at 2 splits; F_2: 150 % recommended NPK at 3 splits; G_1: Recommended planting 60 x 20 cm (83,333 plants/ha); G_2: Clump planting 2 seeds per hill 60 x 40 cm spacing (83,333 plants/ha); G_3: Clump planting 3 seeds per hill 60 x 60 cm spacing (83,333 plants/ha); G_4: Clump planting 4 seeds per hill 60 x 80 cm spacing (83,333 plants/ha); G_5: Paired row of planting 1 seed per hill 45-90-45x 20; G_6: Farmers practice uneven spacing.

Table 5. Soil moisture changes (0-15 cm) under modified planting geometry of corn and fertilizer application rate during 2012 at Raichur.

Planting geometry (G)	Fertilizer rate (F)			Fertilizer rate (F)		
	F_1	F_2	Mean	F_1	F_2	Mean
G_1	6.0	6.2	6.1	5.5	6.1	5.8
G_2	7.3	7.7	7.5	6.8	7.6	7.2
G_3	8.0	8.0	8.0	7.8	7.8	7.8
G_4	10.5	8.4	9.4	9.5	9.1	9.3
G_5	5.1	5.7	5.4	4.8	5.4	5.1
G_6	6.8	4.8	5.8	6.4	4.3	5.3
Mean	7.3	6.8		6.8	6.7	
	S.Em±	C.D (P=0.05)		S.Em±	C.D. (P=0.05)	
F	0.1	NS		0.04	NS	
G	0.3	0.8		0.2	0.5	
G x F	0.7	1.9		0.6	1.6	

G_1: Recommended planting 60 x 20 cm (83,333 plants/ha); G_2: Clump planting 2 seeds per hill 60 x 40 cm spacing (83,333 plants/ha); G_3: Clump planting 3 seeds per hill 60 x 60 cm spacing (83,333 plants/ha); G_4: Clump planting 4 seeds per hill 60 x 80 cm spacing (83,333 plants/ha); G_5: Paired row of planting 1 seed per hill 45-90-45x 20; G_6: Farmers practice uneven spacing;F_1: 100% recommended NPK at 2 splits;F_2: 150 % recommended NPK at 3 splits.

seeds per hill and paired row spacing and farmers practice. It may be due to no intra row competition among plants in equal spaced plants but at the cost of more soil moisture utilization. From the point of conservation of soil moisture, more intra row distance and competition among high dense plants. Similar trend in stover yield was recorded by different planting geometry. Van Roekel and Coulter (2011) found a quadratic-plateau response of corn grain yield to plant density, with the maximum yield occurring at ≥81,700 plants ha^{-1}. Larson and Vanderlip (1994) reported yield variation in sorghum and Lauer and Ramkin (2004) and Liu *et al*. (2004) reported in maize when change in intra row spacing over conventional planting. Graded fertilization is required for clumped plants due to increased competition between plants. When fertilizes applied in three splits have the advantages of available nutrients during later part of the crop growth.

Grain and stover from each clump was harvested separately to estimate grain and stover yield of each clump as influenced by fertilizer application rates and planting geometry (Table 3). Higher grain yield per clump was recorded in 60 x80 cm spacing with 4 seeds/hill compared to other planting combinations. It also recorded lowest biomass yield as compared to rest of the combinations.

Economic returns: Economics of corn production was varied under fertilizer rate and planting geometry (Table 4). In spite of more cost was invested for application of fertilizers @ 225-112.5- 56.25 kg N-P-K/ha (Rs. 33,101/ha) recorded higher gross and net returns. It was mainly due to additional cost of fertilizers. Graded fertilizers produced higher grain yield gross returns and B: C ratio. Among planting geometry combinations sowing of corn at 60 x 40 cm spacing with 2 seeds/hill recorded higher gross returns (Rs. 95,472/ha), net returns (Rs. 64,271/ha) and B: C ratio (2.02) over 60 cm x80 cm spacing with 4 seeds/hill. These economic values are indicated by variation in grain yield and market prices. A decreased yield level in 60 x 80cm spacing was mainly due to competition between plants within clump.

Soil moisture status: Significant changes in soil moisture at different growth stages influenced by fertilizer application rates and planting geometry (Table 5). There was no significant difference between fertilizer application rates at both 45 and 75 days after planting. Among planting geometry significantly higher soil moisture was recorded in 60 x 80 cm spaced with 4 seeds/hill (9.4 and 9.3 %) as compared to conventional planting and other clump plantings. Increase in distance between plants within the row has utilized minimum soil moisture by conserving during early part of the crop growth. Under dryland condition, corn can be grown successfully by soil moisture conservation through clump planting (Mohankumar Kapanigowda *et al*., 2010).

Conclusion

The results of the study indicated that fertilizers applied at 225-112.5- 56.25 kg N-P-K/ha in three splits was better than blanket application. Corn plants are grown in clumps at 60 x 40 cm with 2 seeds/hill was found effective to achieve higher grain and stover yield than conventional recommendation and farmers practice. Reduced biomass production indicated by lower LAI in clumps during vegetative stage indicate lower vegetative growth. The ratio of grain yield to biological yield is also improved by clump planting due to reduced dry matter accumulation. Clump planting will be a useful strategy in corn production for achieving maximum utilization of resources in crop combinations.

ACKNOWLEDGEMENTS

Authors are acknowledged Directorate of Research, University of Agricultural Sciences, Raichur, Karnataka for financial assistance to conduct field trial and service rendered by field crews of MARS, Raichur

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