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Relative impact of in-situ moisture conservation and row spacing's on growth and yield of maize (*Zea mays* L.) varieties under rainfed condition

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Abstract
Rainfed agriculture has a high yield potential if rainfall and land resources are effectively used. In this study, a field experiment was conducted during *kharif*, 2011 at Soil Conservation and Water Management Farm of C.S. Azad University of Agriculture and Technology, Kanpur. The treatment comprised 12 combinations of 2 varieties (Azad Uttam and Azad Kamal), with 2 row spacings (45 and 60 cm) and 3 moisture conservation practices viz. one weeding and hoeing by khurpi after 20 days of sowing, ridging and furrowing with the help of spade at 20 days after sowing in between the crop rows and Atrazine (pre-emergence) @ 1.0 kg a.i./ha. The maximum values of crop growth and yield attributes were recorded in variety 'Azad Uttam' than Azad 'Kamal'. It yielded 24.82 q / ha grain yield, against 21.35 q / ha grain yield, of variety 'Azad Kamal'. The row spacing of 45 cm produced 23.79 q / ha grain yield, against 22.37 q / ha grain yield, under 60 cm row spacing. These findings demonstrate that when there are fluctuations in rainfall, in-situ moisture conservation practices effect growth and yield of maize.

Keywords: maize, varieties, spacing, moisture conservation practices, growth, yield

Introduction
In India, 67 per cent of total cropped area (142 million ha) is rainfed. Rainfed areas are characterized by erratic rainfall and soils with low productivity/soil fertility and organic matter. There is continuing degradation by way of soil erosion, nutrients depletion and runoff losses, which amount to about 50 per cent of total annual rainfall received in the country. Obviously, these losses result in low crop yields. Soil erosion leads to many losses. Firstly, soil is lost and plant nutrients are removed severely. The Central Soil and Water Conservation Research and Training Institute, Dehradun recently estimated production losses of major cereal crops cultivated on degraded soils. Such loss in production of maize crop was estimated 17.6 per cent (Sharda, 2010) [18]. Advantages of plant geometry manipulation in maize on crop production and conservation of resources during *Kharif* rainfed season have also been reported by Bharadwaj *et al.* (1980) [2]. The ridging and furrowing after crop establishment has been found useful even on flat lands, as the practice is helpful to save the crop both during drought as well as wet season. Furrows provide more opportunity and time to runoff water to soak into the soil while the ridges provide adequate aeration to the crop during water inundation or flooding. In various experiments conducted at Kanpur on light textured soil, furrowing in between the rows of crop like maize, jowar, bajra, cotton etc. after establishment followed by shaping the ridges manually brought about substantial increase in yield. Sachan *et al.* (1999) [17] reported that ridging and furrowing between the crop rows 25 days after sowing increased yield attributes, yield and nitrogen uptake as compared to flat seed beds. Pandey *et al.* (2001) [15] found that earthing of the crop proved most effective followed by hand weeding and parquat. The highest grain yield and yield attributes were recorded under alachlor + earthing up of maize crop. Herbicides are getting popularity because of their easiness in application, less time consuming at one hand and economical on the other hand.

Method and material
The field experiment was conducted at Soil Conservation and Water Management Farm of C.S. Azad University of Agriculture and Technology, Kanpur which is situated between 25º26' and 26º 58' North latitude and between 79º31' and 80º34' East longitude at an elevation of 129.0 meters above mean sea level. It lies in central part of Uttar Pradesh. The climate of Kanpur is sub-tropical and semi-arid. The average annual rainfall is around 800 mm. A major portion of rains is received during *monsoon* season from last week of June up to first week of

October. Some occasional showers are also received during winter months. Crop did not suffer from moisture scarcity during any phase of growth and reproduction. Other weather parameters also prevailed normal during crop period which favored the growth and developing of experimental crop. The soil of experimental field is a typical eroded gangetic alluvium representing Kanpur Type-1 to estimate the various soil properties. Soil samples from surface layer of experimental area at 0-15 cm depth were drawn from 5 random places. The soil was having 30.4% sand, 32.4% silt and 35.6% clay with 0.62% organic carbon, 236 kg/ha available N, 18.5 kg/ha available P and 352 kg/ha available K and electrical conductivity 0.29 ds/m in the year of experiment. The total rainfall received during the crop season was 645.8 mm distributed in 37 rainy days. The treatments comprised 12 combinations of 2 maize varieties, 2 row spacing's and 3 in-situ moisture conservation practices. All 12 treatment combinations were tested in Factorial Randomized Block Design with three replications. All treatments were allocated to different plots randomly in each replication. An uniform dose of 80 kg N + 40 kg P_2O_5 + 40 kg K_2O/ha was given through Urea, Diammonium phosphate and Muriate of potash, respectively. Half of total N and full dose of P and K were applied through band placement 2-3 cm below the seed with the help of funnel attached with *Deshi* plough used for seed sowing. Remaining half dose of N was top dressed at 20 days after sowing in standing crop. Sowing of maize varieties was done on July 12, 2011 in furrows behind *Deshi* plough deploying seed @ 25 kg and 18.75 kg/ha in 45 and 60 cm row spacing, respectively. In the treatment plots of weeding and hoeing, one hand weeding and hoeing was done with the help of *khurpi* at 20 DAS to conserve moisture and check the growth of weeds.

Result and discussion

Growth Parameters of Maize

The data on plant stand, stem girth crop canopy, number of days to 50% tasseling, number of days to maturity, number of roots per plant and dry weight of roots per plant are presented in table 1. The data clearly indicated that varieties and moisture conservation practices had no significant effect on plant stand of maize at any stage of observation. Plant stand was significantly influenced by row spacings, where 45 cm row spacing maintained significantly higher plant population than 60 cm row spacing at both stages of initial and final observation. At both stages, 45 cm row spacing maintained about 32.7 per cent higher plant population than 60cm row spacing. None of the interactions effect was found significant or initial on final plant stand. Plant spacing with in row was maintained uniform in both row spacing, therefore, closer row spacing of 45 cm could maintained significantly more plant stand than wider row spacing of 60 cm. The plant growth parameters, both above ground viz., plant height, stem girth and crop canopy and below ground viz., root length, number of roots/plant and dry root weight/plant were recorded significantly higher in variety 'Azad Uttam' than 'Azad Kamal', and in ridging and furrowing practice than other two moisture conservation practices.

In general, plant height increased with age of plant irrespective of treatments. The rate of increase in plant height was observed highest between 30 and 45 days stages followed by between 45 and 60 days stages. All the three treatment factors affected plant height at all stages of observation except at 30 DAS when difference between row spacing could not touch the level of significance. Variety 'Azad Uttam' produced taller plants than 'Azad Kamal' in all cases with the margin of 29.8 per cent at final stages of harvest.

Among row spacings, 45 cm spacing recorded significantly more plant height than 60 cm spacing in all cases. At final stage of crop harvest, 45 cm row spacing recorded 19.2% more plant height over 60 cm row spacing. In case of moisture conservation practices, furrowing and ridging practice produced significantly tallest plant at almost all stages of observation. Other both practices remained at par with each other in this respect. However, hand weeding recorded numerically more plant height than atrazine treatment.

The stem girth of maize improved with plant age up to 60 DAS when maximum girth was recorded irrespective of treatments. At last stage of harvest, stem girth slightly declined. The variety 'Azad Uttam' recorded significantly more stem girth than 'Azad Kamal' in all observations. At maximum girth stage of 60 DAS, variety 'Azad Uttam' showed 25.3 per cent more stem girth than the variety 'Azad Kamal'.

The effect of row spacing was not found significant on stem girth in earlier two observations at 30 and 45 DAS, but at later both stages, stem girth was recorded significantly higher under 60 cm row spacing than 45 cm wider rows. At maximum girth stage of 60 DAS, the difference between two row spacing was worked out 15.5 per cent higher in favor of 60 cm row spacing.

Among different moisture conservation practices, furrowing and ridging recorded significantly maximum stem girth, while other two practices were found at par with each other. The results remained similar in all observations. At the stage of 60 DAS, ridging and furrowing practice recorded 9.3 and 18.2 per cent more stem girth than one weeding and hoeing and atrazine practices, respectively.

The canopy expansion improved with crop age and maximized at the stage of 60 DAS irrespective of treatments. As regards treatment effects, variety 'Azad Uttam' showed dense crop canopy than variety 'Azad Kamal' in all observations, however at 30 days stage, difference between varieties was not up to significant level. Among row spacings, 45 cm spacing recorded dense canopy than 60 cm wider rows. In case of moisture conservation practices, furrowing and ridging (M_2) showed significantly maximum crop canopy at all three stages of observation. Other both practices (M_1 and M_3) recorded crop canopy at par with each other in all observations.

The variety 'Azad Kamal' was earlier in tasseling by about a week than 'Azad Uttam' with significant margin. Among row spacing, 45 cm showed earlier tasseling by 3 days than wider rows of 60 cm with significant difference. In case of moisture conservation practices, hand weeding (M_1) and atrazine (M_2) being at par took about 5 days lesser time for tasseling than furrowing and ridging treatment (M_2).

The plants of variety 'Azad Kamal' matured about 10 days earlier than variety 'Azad Uttam' with significant margin. Though, row spacing of 45 cm showed 2 days earlier maturity than 60 cm row spacing, but this difference could not touch the level of significance. Among moisture conservation practices, hand weeding (M_1) and Atrazine (M_3) treatments being at par earlier crop maturity than the treatment of furrowing and ridging (M_2) by about 5 days margin.

The depth of root (cm) was influenced markedly by all the three treatment factors of study. Variety 'Azad Uttam' produced deeper roots than 'Azad Kamal' by the margin of 18.8 per cent. Among row spacings, 45 cm produced deeper

roots than wider rows of 60 cm by the margin of 11.5%. In case of moisture conservation practices, hand weeding treatment closely followed by Atrazine treatment produced deeper roots than furrowing and ridging.

The data clearly indicate that number of roots was affected by main effect of all treatment factors. Variety 'Azad Uttam' produced more number of roots than 'Azad Kamal' by the margin of 22.2 per cent. In case of row spacing, 60 cm spacing produced significantly more number of roots as compared to 45 cm row spacing by the margin of 7.9%. Among moisture conservation practices, furrowing and ridging treatment recorded maximum number of roots per plant (55.90), while minimum number of 47.30 roots/plant were counted under hand weeding treatment. Thus, the ridging and furrowing treatment of furrowing and ridging produced 9.1 and 18.2% more number of roots than the treatments of Atrazine and hand weeding, respectively in this character also.

It is obvious from the data that variety 'Azad Uttam' recorded higher dry weight of roots than variety 'Azad Kamal' by the margin of 15.7 per cent. The 60 cm row spacing recorded numerically 8.9 per cent of more dry root weight than 45 cm row spacing. Among moisture conservation practices, furrowing and ridging treatment recorded highest dry weight of roots (16.78 g) followed by Atrazine treatment (14.60 g) and hand weeding treatment (13.37 g).Treatment under ridging and furrowing recorded 14.9 and 25.5% higher dry weight of roots as compared to Atrazine and one weeding and hoeing treatments, respectively.

The better performance of variety 'Azad Uttam' than 'Azad Kamal' might be due to genetic makeup of 'Azad Uttam' which took the advantage of available growth resources in a better way than other variety 'Azad Kamal' under different growing conditions. The maximum values of various growth parameters under ridging and furrowing practice might be attributed to exposure of plant roots to more soil volume because of earthing which increased the uptake of nutrients along with more moisture utilization from furrows. These results corroborate with the findings of **Gupta and Bhan (1993), Singh and Verma (1995)** and Pandey *et al.,* (2001) [15].

Table 1: Effect of treatments on plant stand, stem girth, crop canopy, number of days to 50% tasseling, number of days to maturity, number of roots and dry weight of roots per plant of maize

Treatment / Varieties	Initial plant stand (000/ha)	Final plant stand (000/ha)	Plant height (cm)	Stem girth (cm)	Crop canopy development (%)	Number of days to 50% tasseling	Number of days to maturity	Number of roots per plant	Dry weight of roots/plant (g)
Azad Uttam	97.22	92.50	190.0	7.04	71.6	53.00	87.33	56.63	16.00
Azad Kamal	97.50	92.30	146.4	5.50	60.0	45.33	77.00	46.33	13.83
S.Ed. ±	2.72	2.09	5.1	0.19	1.3	0.67	1.21	-	-
C.D. (P = 0.05)	NS	NS	10.5	0.39	2.7	1.39	2.50	-	-
Row spacings-cm									
45	111.03	105.37	182.9	5.85	68.5	47.83	81.17	49.53	14.28
60	83.68	79.43	153.5	6.78	63.1	50.50	83.17	53.43	15.55
S.Ed. ±	2.72	2.09	5.1	0.19	1.3	0.67	1.21	-	-
C.D. (P = 0.05)	5.64	4.34	10.5	0.39	2.7	1.39	NS	-	-
Moisture conservation practices									
One weeding and hoeing by *khurpi*	96.95	92.50	160.3	5.27	62.3	47.75	81.00	47.30	13.37
Ridging and furrowing	97.50	91.65	187.8	6.87	74.6	52.75	85.50	55.90	16.78
Atrazine @ 1.0 kg a.i./ha (pre-emergence)	97.62	93.05	156.5	5.80	60.5	47.00	80.00	51.25	14.60
S.Ed. ±	3.33	2.56	6.2	0.23	1.6	0.82	1.48	-	-
C.D. (P = 0.05)	NS	NS	12.9	0.47	3.2	1.71	3.07	-	-

Yield attributes and yield

The yield attributes of maize studied in present experiment were number of cobs/plant, cob length, weight/main cob, grains/main cob, grain weight/main cob and 1000-grain weight. All attributes except 1000-grain weight were recorded significantly higher in variety 'Azad Uttam' than 'Azad Kamal' (Tables-2). These are attributed to better growth characters of 'Azad Uttam' which is mainly due to genetical character of variety. Pandey *et al.* (2002) [14] and Pal and Bhatnagar (2009) [13] also reported similar varietal variations in yield attributes of maize. Among row spacings, 60 cm spacing registered significantly higher values of all yield attributes except 1000-grain weight test weight than 45 cm row spacing. It might be attributed to lesser competition between crop plants for space, moisture, nutrients and light as compared to 45 cm row spacing. Thus, plants in wider rows utilized growth resources in better way and improved yield attributes over closer row spacing. These results are in conformity with the findings of Kar *et al.* (2006) [8], Kumar (2008) [9], Sharma and Gautam (2010) [19] and Neupane *et al.* (2011) [12]. In case of moisture conservation practices, ridging and furrowing practice registered significantly maximum values of all yield attributes except 1000-grain weight. Among other two practices, one weeding and hoeing by *khurpi* improved yield attributes over Atrazine treatment but difference was found significant only in case of cobs/plant and cob length. The best performance of ridging and furrowing practice might be attributed to exposure of roots to more soil volume because of earthing which increased the availability and uptake of more nutrients by crop plants along with more moisture absorption. Comparatively better performance of one weeding hoeing by *khurpi* and over Atrazine treatment might be due to better aeration in soil which increased the root development and activity thereby producing higher yield attributes. These results corroborate with the findings of Sachan *et al.* (1999) [17], Pandey *et al.* (2001) [15], Kureel (2004) [10] and Sharma and Gautam (2010) [19]. Grain and stover yields of maize were recorded significantly higher in variety 'Azad Uttam' than

'Azad Kamal'. These might be attributed to higher growth parameters and yield attributes in variety 'Azad Uttam'. The possible reasons for those have already been discussed on prior pages. Similar was the case with biological yield of maize which was also recorded higher in 'Azad Uttam'. However, yield potential of any genotype is governed by its genetic make-up. Therefore, it is purely a varietal character. Yield variations between maize genotypes have already been reported by Pal and Bhatnagar (2009) [13]. Row spacings of 45 and 60 cm did not differ significantly from each other in grain or stover yield per unit area. Though, various yield attributes were higher under 60 cm row spacing but it could not increase the yields/unit area perhaps because of lesser plant stand per unit area. On the other hand, in 45 cm row spacing, growth and yield attributes were lower than 60 cm row spacing but because of higher plant stand/unit area, it could complete with 60 cm row spacing by producing grain and stover yields per unit area at par with wider row spacing of 60 cm. Moreover, higher plant population under 45 cm row spacing could take full advantage of available soil moisture because of wide spread sufficient rains in crop period. These results may be supported by the findings of Chaudhary *et al.* (1992) [3], Tyagi *et al.* (1998) [22], stone *et al.* (2000) [21], Raja (2001) [16] and Maqbool *et al.* (2006) [11]. Out of three moisture conservation practices, ridging and furrowing recorded significantly highest grain and stover yields, while other two practices remained at par with each other (Tables-4.18 and 4.19). These yields might be attributed to yield attributes and growth parameters which also observed to be the highest under ridging and furrowing practice. The possible reasons for those have already been discussed on prior pages of discussion. These results are in accordance with the findings of Jat *et al.* (2005) [6], Girma *et al.* (2005) [4], Uttam *et al.* (2007) [23], Arulkumar *et al.* (2008) [1] and Sharma and Gautam (2010) [19].

Table 2: Effect of treatments on plant stand, stem girth, crop canopy, number of days to 50% tasseling, number of days to maturity, number of roots and dry weight of roots per plant of maize

Treatment Varieties	Number of cobs/plant	Length of main cob (cm)	Weight/main cob (g)	Number of grains/main cob	Grain weight/cob (g)	1000-grain weight (g)	Grain yield (q/ha)	Stover yield (q/ha)
Azad Uttam	1.48	16.03	54.22	227.92	34.33	170.03	24.82	74.17
Azad Kamal	1.28	13.54	43.38	176.87	28.28	164.17	21.35	64.16
S.Ed. ±	0.05	0.27	1.07	5.12	1.00	3.53	0.82	2.24
C.D. (P = 0.05)	0.10	0.57	2.21	10.62	2.06	NS	1.70	4.65
Row spacing's-cm								
45	1.30	14.05	45.50	195.15	29.20	166.53	23.79	71.43
60	1.47	15.38	52.10	209.68	33.42	167.67	22.37	66.90
S.Ed. ±	0.05	0.27	1.07	5.12	1.00	3.53	0.82	2.24
C.D. (P = 0.05)	0.10	0.57	2.21	10.62	2.06	NS	NS	NS
Moisture conservation practices								
One weeding and hoeing by *khurpi*	1.33	14.55	47.72	198.15	30.60	166.48	22.35	67.12
Ridging and furrowing	1.63	15.98	52.93	218.25	33.95	168.75	25.63	76.05
Atrazine @ 1.0 kg a.i./ha (pre-emergence)	1.20	13.57	45.75	190.78	29.85	166.08	21.37	64.32
S.Ed. ±	0.06	0.34	1.30	5.27	1.22	4.32	1.01	2.75
C.D. (P = 0.05)	0.12	0.70	2.71	13.01	2.53	NS	2.09	5.70

Conclusion

The results of present study may be concluded that the ridging and furrowing practice at 20 days after sowing in between the crop rows resulted in best crop growth with growth parameters, highest crop yields. Moreover, Crop plants under wider row spacing of 60 cm attained better growth and root development in both varieties, but total water use by crop and crop yields were higher under 45 cm row spacing.

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