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Study about the interaction effects on varieties and plant geometry on growth and yield of hybrid and composite maize (*Zea mays* L.) on *rabi* season

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Abstract
An experiment was conducted at Agronomy research Farm of C.S.A University of Agriculture and Technology, Kanpur (U. P), during winter season in 2010-11 and 2011-12. The experiment was laid out in split plot design with three replications. The main plots were occupied by maize hybrid (cv DHM-117) and composite (cv Madhuri) along with three plant geometry, 45cm x 20 cm (1,11,111 plants/ha), 60cm x 20 cm (83,3,33 plants/ha) and 60cm x 25 cm (66,6,66 plants/ha) and sub plot was allotted by three fertility levels *viz*, F_1- N, 120 kg, P_2O_5, 60 kg, K_2O, 40 kg and $ZnSo_4$, 15 kgha^{-1}, F_2 - N, 150 kg, P_2O_5, 80 kg, K_2O, 60 kg and $ZnSo_4$, 20 kgha^{-1} and F_3 - N, 180 kg, P_2O_5, 100 kg, K_2O, 80 kg and $ZnSo_4$, 25 kgha^{-1}. The experiment results revealed that all the growth and yield parameters like plant height (cm), number of leaves/plant, dry weight (g/m^2) and leaf area index (LAI), maize grain and stover yield (t/ha) and harvest index % (HI%) at harvest stage were found significant interaction between varieties and plant geometry. The maize hybrid was found better than Composite in among parameters. Plant geometry 60cm x 20cm was obtained significantly maximum yield (6.7 t/ha) compared to plant geometry 45cm x 20cm (6.20 t/ha), 60cm x 25cm (6.15 t/ha), respectively. In various fertility levels F_1 was found superior followed by F_2 and F_3 treatments, respectively. While the harvest index (%) and Shelling (%) were did't found significant in among the treatments.

Keywords: Maize, plant geometry, interaction, NPK and Zn, LAI, HI%, yield

Introduction
Maize (*Zea mays* L.) is one of the important cereal crops next to wheat and rice in the world. In India, it ranks third after rice and wheat. Maize is being consumed both as food and fodder and also required by the various industries. In the world, it is grown over an area of 131 mha with an annual production of 506 mt with productivity of 3890 kg ha^{-1} (Anonymous, 2013-14) [2]. In India, it is cultivated over an area of 9.3 mha with an annual production of 24.2 mt and productivity of 2602 kg /ha during *rabi* season (Anonymous, 2013-14) [2]. In Uttar Pradesh, the area, production and productivity of maize were 0.70 m ha, 2.30 mt, 3131 kg/ha, respectively (Anonymous, 2012-13). In India, about 35 per cent of the maize produced, which 60 per cent is used for human consumption, 25 per cent each in poultry feed and cattle feed and 15 per cent in food processing like corn flakes, popcorn *etc.* and in other industries mainly starch, dextrose, corn syrup and corn oil *etc.* Maize yield is closely related to plant population. More plants mean higher yield. However, there is limitation to increasing plant population under humid, tropical conditions. Maize becomes more susceptible to pests and diseases when temperature, rainfall, and humidity are high. The number of plants per unit area is influenced by the distance between row and distance between plants in row. Select an optimum plant spacing that allows for ease of the field operations, such a fertilizer application and weeding, minimizes competition among plants for light, water and nutrients and creates a favorable micro-climate for the canopy that reduced the risk for pests and diseases. Narrow row width of about 50 to 70 cm is recommended to ensure that sunlight falls on the plants and not on bare soil. This reduced weed competition and loss of soil moisture from evaporation. Maize is one of the most important cereal crops grown in tropical and temperate region of the world. Despite its high yield potential, it is giving low yields because of lack of appropriate information on varieties, plant geometry and fertilizer management. Nitrogen, phosphorus and potassium are the major plant nutrients, which limit normal plant growth increasing productivity per unit area through inorganic management is one of the important strategies to increasing the production of maize grain.

Materials and Mathods

The experimental field was conducted at the Students Instructional farm, C. S. Azad University of Agriculture and Technology, Kanpur during winter season 2010-11 and 2011-12. Farm is situated on the University campus at $26^0$29'35 North latitude and $80^0$18'25 east longitude. Elevation from mean sea level is 125.9 meter. Experimental field was well leveled and had assured irrigation facility by tube well. It is situated in alluvial belt of middle Gangatic plain in central part of Uttar Pradesh having class second of land capability. This zone has semi-arid climatic conditions having alluvial fertile soil. The normal rainfall of the area is about 890 mm per annum. Most of the rains are received from June to the end of the September. The winter months are cooler with occasional frost during last week of December to mid-January. The temperature in May and June may go up to 44-47 ^{0}C or beyond this while the minimum temperature during winter goes to 2-3 ^{0}C. Mean relative humidity (7 a.m.) remains nearly constant at about 80-90% from July to end of March and afterwards slowly declines to about 40-50% by the end of April and remains 80% up to June. The treatments comprised two maize (cv DHM-117) and composite (cv Madhuri) and three plant geometry 45x20cm (1,11,111 plants/ha), 60x20 cm (83,3,33 plants/ha) and 60x25 cm (66,6,66 plants/ha) in main plots and three fertility levels *viz.* N, P_2O_5, K_2O and $ZnSO_4$ (180, 100, 80 and 25 kg/ha), N, P_2O_5, K_2O and $ZnSO_4$ (150, 80, 60 and 20 kg/ha) and N, P_2O_5, K_2O and $ZnSO_4$ (120, 60, 40 and 15 kg/ha) in sub plots. The treatments were evaluated in split plot design with three replications. The experiment was sown on 30th October in 2010 and on 16th October in 2011. The application of nitrogen and phosphorus was done in the form of urea and DAP. Potash and zinc were supplied in the form of muriate of potash and zinc sulphate as per the treatments. The crop was harvested at full ripe stage on 24th April and 10th April, in 2010 and 2011, respectively.

Soil of experimental field

The experimental field was well drained and leveled. The samples were taken with augar from 0-15 cm depth in field and collected randomly from different places of the experimental field for physico-chemical analysis before execution of fertility treatments. The collected samples were mixed together and composite sample was drawn and analyzed. The details of soil properties have been presented in Table 1. According to triangular method of soil classification recognized by International Society of Soil Science, the soil of the field may be classified as sandy loam in texture having pH 7.5-7.6. The water table at the time of sowing was around 2.55 m from ground surface in both the season.

Table 1: Initial physico-chemical properties of experimental soil

S. No	Particular	Experimental value		Method employed
		2010	2011	
A.	**Physical properties**			
1.	Sand (%)	53.90	54.00	Pipette method (Piper, 1966)
2.	Silt (%)	23.10	23.20	
3.	Clay (%)	21.50	21.80	
4.	Textural class	sandy loam		Triangular method
B.	**Chemical properties**			
5.	Soil pH (1:2.5) (soil :water)	7.50	7.60	Blackman's pH meter (Piper, 1950)
6.	Organic carbon (%)	0.43	0.45	Walkley and Black' s method (Jackson, 1973)
7.	Electrical conductivity(dSm^{-1})	0.32	0.36	Solubridge method(Jackson, 1973)
8.	Available N (kg ha^{-1})	179.60	180.50	Modified Kjeldahl method (Jackson, 1973)
9.	Available P (kg ha^{-1})	19.10	19.20	Olsen's, method (Olsen *et al.* 1954)
10	Available K (kg ha^{-1})	128.00	128.25	Flame photometer (Jackson, 1973)
11.	Available Zn (ppm)	0.74	0.76	DTPA extract(Lindsay and Norvell, 1978)

Leaf area per plant

Leaf area was measured by the following formula

Leaf area = Leaf length × Leaf breath × factor.

The length of the fully opened leaf lamina was measured from the base to the tip. Leaf breath was taken at the widest point of the leaf lamina. The product of the leaf length and breadth was multiplied by the factor 0.75 (Saxena and Singh, 1965) [13] and the sum of leaf area of all the leaves was expressed as cm^2 per plant.

Calculation

Leaf area index (LAI)

LAI was calculated as per the procedure given by Sestak *et al.* (1971)

$$LAI = \frac{A}{P}$$

Where,

A: Leaf area per plant (cm^2)

P: Land area covered by individual plant (cm^2

Shelling (%)

$$\text{Shelling percent} = \frac{\text{Grain weight per cob}}{\text{Cob weight}} \times 100$$

Harvest index (%)

Harvest index is defined as the ratio of economic yield to total biological yield (Donald, 1962) [4] and expressed in percentage. The harvest index for maize was worked out as indicated below.

$$\text{Harvest index \%} = \frac{\text{Economic yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

Results and Discussion

Plant height

Maximum plant height (227.73 and 232.28 cm) was recorded under hybrid maize (cv DHM-117) as compared to composite maize (cv Madhuri) at harvest stage (table 1).The differential growth with respect to plant height observed both the varieties may be attributed to differences in genetic characteristics of the individual varieties, including rapid growth rates, tallness or shortness of species, Pal and Bhatnagar (2012) [10] that attributed the differences in growth indices of crops to genetic constitution. Plant geometry 60cm x 20 cm (83, 3, 33 plants/ha) had taller plant than geometry 45x20 cm (1, 11,111 plants/ha) and 60cm x 25cm (66, 6, 66 plants/ha) possibly because of increased competition for space, sunlight and available nutrients Laskari (2011) [8]. Application of successive dose of N, P_2O_5, K_2O and $ZnSO_4$ of (180, 100, 80 and 25 kg/ha) F_3 treatment was obtained taller plant than application N, P_2O_5, K_2O and $ZnSO_4$ of (150, 80, 60 and 20 kg/ha) F_2 and N, P_2O_5, K_2O and $ZnSO_4$ of (120, 60, 40 and 15 kg/ha) F_1, respectively in 2010-11 and 2011-12. Availability of higher nutrition to the growing plant might have resulted in better growth of plant resulted in terms of higher plant height. Similar results of increased plant height with higher doses of nitrogen, phosphorus, and potash and zinc fertilizers were reported by Paramasivan *et al.* (2011) [11].

Number of Leaves

The maximum number of leaves were observed with hybrid maize (CV DHM-117) as compared to composite (CV Madhuri). The differences observed in the number of leaves of maize may be attributed to differences in growth characters which are being influenced by genetic make-up of the plants Gollar *et al*. (1996) [5]. Maize plant sown at plant geometry 60x20 cm had higher number of leaves than plant geometry 45cm x 20 cm and 60cm x 25 cm because of increased growth rate in search for space, sunlight and other environmental resources. The higher number of leaves and probably higher chlorophyll content under the higher nitrogen levels made the crop photo synthetically more active and therefore higher dry matter accumulation at all the growth stages with the application of N, P_2O_5, K_2O and $ZnSO_4$ (180, 100, 80 and 25 kg/ha) F_3 compared to N, P_2O_5, K_2O and $ZnSO_4$ of (150, 80, 60 and 20 kg/ha) F_2 and N, P_2O_5, K_2O and $ZnSO_4$ of (120, 60, 40 and 15 kg/ha) F_1 (Table-1).

Leaf area index (LAI)

The differences observed in leaf area index of the varieties of maize sown could be attributed to the differences in leaf arrangement, photosynthetic activities of leaves, differences in chlorophyll content and activity of photosynthetic enzymes Kaliq *et al.* (2010) [7]. plant geometry 60cm x 20 cm recorded significantly higher leaf area index compared to plant geometry 45cm x 20 cm and 60cm x 25 cm. This might be due to larger leaf area index possibly because of reduction in competition for space, sunlight and nutrients within the wider spaced plants, Thavaprakaash *et al.* (2005) [15]. Leaf area index of maize plant was significantly influenced by fertility levels. This might be probably due to higher chlorophyll content under the higher fertility levels N, P_2O_5, K_2O and $ZnSO_4$ of (180, 100, 80 and 25 kg/ha) which made the crop photosynthetically more active Reddi and Reddy (2007).

Dry Matter (g/m^2)

The dry matter increased progressively up to the harvest stage in both the years (Table-1). Significantly higher dry matter accumulation was observed with maize hybrid (CV DHM-117) followed by maize composite (CV Madhuri). This ultimately resulted in greater portion of dry matter to leaves which might have resulted in higher photosynthetic efficiency and higher grain and stover yield of maize, Iptas and Acar *et al.* (2006). Plant geometry 60 cm x 20 cm recorded higher dry matter accumulation followed by plant geometry 60cm x 25 cm and 45cm x 20 cm. This might be due to maximum plant height, number of leaves, and leaf area index resulting in more dry matter accumulation per meter^2. Similar results were discussed by Thavaprakaash *et al.* (2005) [15]. The maximum dry matter obtained from the application of N, P_2O_5, K_2O and $ZnSO_4$ of (180, 100, 80 and 25 kg/ha) followed by N, P_2O_5, K_2O and $ZnSO_4$ of (150, 80, 60 and 20 kg/ha) and N, P_2O_5, K_2O and $ZnSO_4$ of (120, 60, 40 and 15 kg/ha) (table 1). This may be due plants more uptake nutrient from the soil which cause maximum growth of plant, no of leaves, leaf area index, chlorophyll accumulation in leaf results maximum dry matter.

Table 1: Plant height (cm), number of leaves/plant, dry weight (g/m^2) and leaf area index at harvest stage of maize plant as influenced by variety, plant geometry and fertility levels.

Treatment	Plant height(cm) at harvest stage		Number of leaves at harvest stage		Dry weight (g/m^2) at harvest stage		Leaf area index at harvest stage	
	2010	2011	2010	2011	2010	2011	2010	2011
Variety								
Composite maize (cv Madhuri)	184.27	188.20	12.84	13.10	369.28	369.29	3.70	3.78
Hybrid maize (cv DHM-117)	227.73	232.28	15.87	16.19	456.38	469.14	4.57	4.66
S Em ±	3.11	2.77	0.20	0.20	5.56	4.66	0.05	0.05
CD (P=0.05)	9.82	8.75	0.63	0.64	17.53	14.70	0.18	0.18
Plant geometry								
45cm x 20 cm (1,11,111.11 plants/ha)	204.01	208.06	14.23	14.51	408.83	416.99	4.10	4.18
60cm x 20 cm (83,3,33.33 plants/ha)	214.61	218.91	14.97	15.27	430.55	439.08	4.31	4.40
60cm x 25 cm (66,6,66.66 plants/ha)	199.38	203.74	13.87	14.15	399.11	401.52	4.00	4.08
S Em ±	3.81	3.40	0.24	0.24	6.81	5.71	0.07	0.07
CD (P=0.05)	12.02	10.72	0.78	0.78	21.47	18.01	0.22	0.22
Fertility levels								
N, 120 kg, P_2O_5, 60 kg, K_2O, 40 kg and $ZnSo_4$, 15 kgha^{-1}.	186.25	190.36	12.98	13.23	373.23	380.63	3.74	3.81
N, 150 kg, P_2O_5, 80 kg, K_2O, 60 kg and $ZnSo_4$, 20 kgha^{-1}.	209.33	213.48	14.60	14.89	419.53	416.78	4.21	4.29
N, 180 kg, P_2O_5, 100 kg, K_2O, 80 kg and $ZnSo_4$, 25 kgha^{-1}.	222.42	226.87	15.49	15.82	445.75	460.19	4.47	4.56
S Em ±	2.48	2.37	0.20	0.21	5.71	6.25	0.06	0.06
CD (P=0.05)	7.25	6.91	0.60	0.62	16.69	18.25	0.17	0.18

Table 2: grain and stover yield, harvest index (%) and shelling (%) of maize plant as influenced by variety, plant geometry and fertility levels

Treatment	Grain yield (t/ha)		Stover yield (t/ha)		Harvest index (%)		Shelling (%)	
	2010	2011	2010	2011	2010	2011	2010	2011
Variety								
Composite maize (cv Madhuri)	5.70	5.80	10.76	10.86	34.55	34.74	82.96	83.07
Hybrid maize (cv DHM-117)	7.02	7.17	12.66	12.85	35.66	35.78	84.77	82.82
S Em ±	0.06	0.09	0.13	0.13	0.41	0.55	1.85	1.29
CD (P=0.05)	0.21	0.29	0.42	0.42	NS	NS	NS	NS
Plant geometry								
45cm x 20 cm (1,11,111.11 plants/ha)	6.29	6.42	11.62	11.77	35.22	35.28	82.99	82.91
60cm x 20 cm (83,3,33.33 plants/ha)	6.70	6.	11.97	12.23	35.41	35.40	82.92	82.98
60cm x 25 cm (66,6,66.66 plants/ha)	6.15	6.28	11.53	11.56	34.67	35.09	85.69	82.94
S Em ±	0.08	0.11	0.16	0.16	0.51	0.67	2.26	1.59
CD (P=0.05)	0.25	0.36	0.52	0.52	NS	NS	NS	NS
Fertility levels								
N, 120 kg, P_2O_5, 60 kg, K_2O, 40 kg and $ZnSo_4$, 15 $kgha^{-1}$.	5.80	5.86	10.88	11.03	34.54	34.62	82.92	83.07
N, 150 kg, P_2O_5, 80 kg, K_2O, 60 kg and $ZnSo_4$, 20 $kgha^{-1}$.	6.46	6.59	11.86	12.03	35.17	35.34	83.08	83.12
N, 180 kg, P_2O_5, 100 kg, K_2O, 80 kg and $ZnSo_4$, 25 $kgha^{-1}$.	6.90	7.00	12.38	12.51	35.60	35.82	85.60	82.64
S Em ±	0.07	0.08	0.13	0.15	0.28	0.44	1.91	1.71
CD (P=0.05)	0.23	0.23	0.40	0.44	0.82	NS	NS	NS

Grain and sotver yield

Maximum grain yield (7.02 and 7.17 t/ha) and stover yield (12.66 and 12.85 t/ha) was observed with maize hybrid (CV DHM-117) compared to composite (CV Madhuri) in 2010-11. This might be due to genetic makeup of the plant, internal morphological characters, insect and disease resistance which caused plant to take up more nutrient from the soil resulting in maximum growth parameters *viz.* plant height, number of leaves/plant, dry matter accumulation, leaf area index. These in turn enhanced photosynthetic efficiency and yield attributes likes, no of cobs/plant, no of rows/cob, no of grains/row, no of grains/cob, length of cob, girth of cob, weight of cob, weight of grains/cob, 100-grains weight and yield and produced higher grain and stover yield. Similar results were reported by Pal and Bhatnagar (2009) [9]. The plant geometry 60 cm x 20 cm getting higher grain and stover yield. This might be due to plant receive more sunlight by the canopy of plant and intake sufficient nutrient from the soil which results higher growth of plant and maximum yield attributes, Rao (2010) [12]. Application of N, P_2O_5, K_2O and $ZnSO_4$ (180, 100, 80 and 25 kg/ha, respectively) F_3, recorded significantly higher grain yield (6.86 and 7.00 t/ha) and stover yield (12.38 and 12.51 t/ha). It was significantly superior over F_1 and F_2 treatments, respectively. The lower dose of fertilizes N, P_2O_5, K_2O and $ZnSO_4$ (120, 60, 40 and 15 kg/ha) F_1, recorded the lower grain and stover yield. This might be due to the fact that higher levels of NPK and Zn led to adequate supply of nutrients to the plant resulting in better growth which in turn led to better physiological process and movement of photosynthates to sink, Paramasivan *et al.* (2011) [11].

Interaction Effect

Significant ($P<0.05$) linear interaction effect was found between maize varieties and plant geometry on plant height (cm), number of leaves/plant, dry matter accumulation (g/m^2), leaf area index, grain and stover yield (t/ha) and harvest index (HI%) at harvest stage depicted in Fig. 1, 2, 3, 4, 5, 6 and 7. The maize composite variety Madhuri grain yield (6.15 and 6.27 t/ha) was obtained at plant geometry 45cmx20cm and minimum yield (6.15 and 6.28 t/ha) was obtained at plant geometry 60cm x 25cm. In case of maize hybrid variety DHM-117 along with plant geometry 60cm x 20cm was obtained maximum grain and stover yield, which was at par with plant geometry 60cm x 25cm and lowest grain and stover yield recorded with plant geometry 45cm x 20cm. The maize DHM-117 grown at plant geometry 60x20 produced maximum grain and stover yield. This might be due to wide plant geometry around the individual plant. Plant received more sunlight, nutrient and aeration due to which more photosynthate accumulation having in leaves cause maximum leaf area index, plant height, dry matter accumulation results maximum grain and stover yield, Balibinat *et al.* (2007) [3].

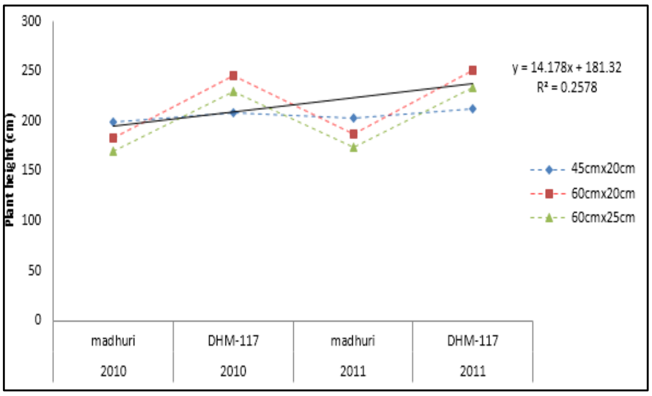

Fig 1: Interaction between varieties and plant geometry in 2010-11

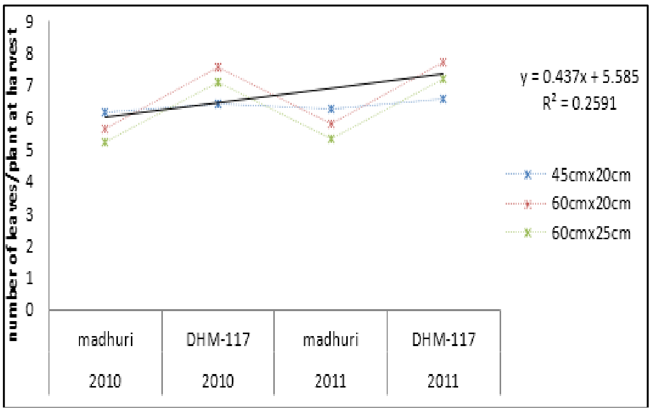

Fig 2: Interaction between varieties and plant geometry

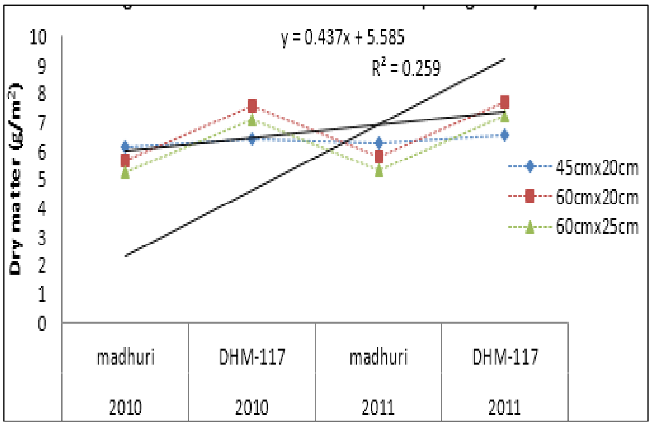

Fig 3: Interaction between varieties and plant geometry

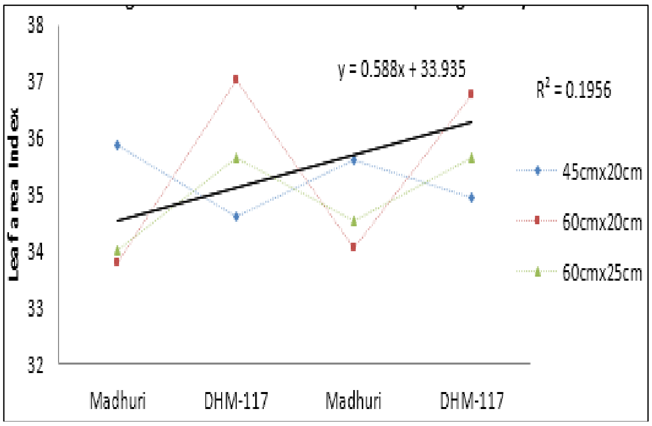

Fig 4: Interaction between varieties and plant geometry

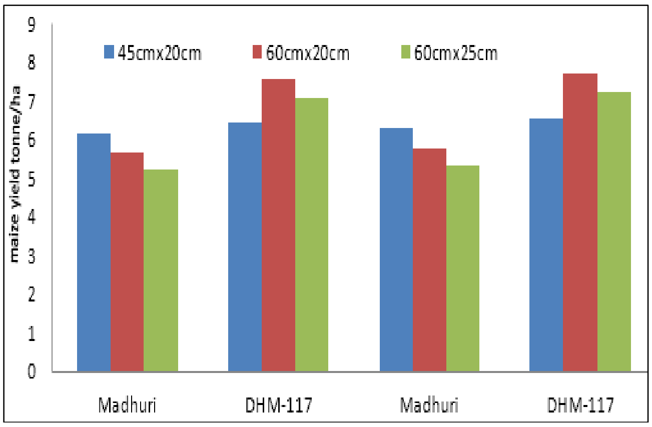

Fig 5: Interaction between maize varieties and plant geometry in 2010-11

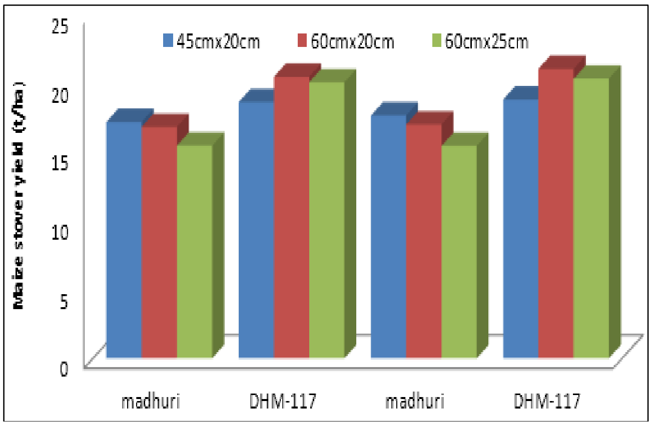

Fig 6: Interaction effect between maize varieties and plant geometry in 2010-11

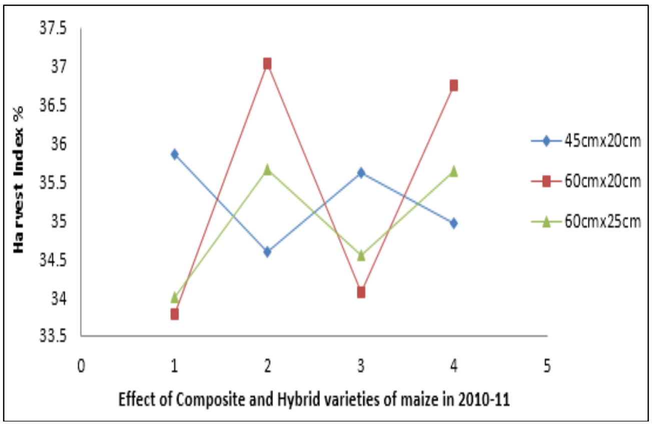

Fig 7: Intraction effect between varieties and plant geometry

Hybrid maize (DHM-117)

Composite maize (Madhuri)

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