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Effect of crop geometry and nitrogen management on growth attributes of pearl millet (*Pennisetum glaucum* L.) under guava based agri-horti system

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Abstract
A field experiment was conducted at RGSC Agricultural Research Farm, BHU, Barkachha, Mirzapur (UP) during kharif season of 2019-20 with aim to find out the effect of 3 crop geometry (45 x 15cm, 40 x 20cm and 30 x 20cm) and 4 levels of nitrogen management (0 kg N ha^{-1}, 100% RDN by urea, 75% RDN by urea + 25% RDN by OM, 50% by urea + 50% by OM) on pearlmillet (*Pennisetum glaucum* L.) under guava (*Psidium guajava* L.) based agri-horti system. The experiment was laid out in Factorial Randomized Block Design and was replicated three times. Results of the experiment revealed that the crop geometry of spacing 40 x 20cm showed higher dry matter accumulation $plant^{-1}$, number of internode $plant^{-1}$, internode length, number of tillers $plant^{-1}$, Leaf area index, crop growth rate and relative growth rate of pearlmillet whereas higher plant height was recorded with crop geometry of 30 x 20cm. Moreover, the application of 100% RDN by urea exhibited higher in all growth parameters, over rest of the nitrogen management.

Keywords: Agri-horti system, crop geometry, guava, growth, nitrogen management, pearlmillet

Introduction
Agri-horticultural system is a modified traditional cropping system of India that utilizes the maximum capability of land as well as growing season and simultaneously enhances the productivity of land. Cereal crops along with Guava, Bael, Aonla, Custard apple and Karonda etc. are more commonly grown in Vindhyan region under the agri-horticultural system (Pal *et al.*, 2014) [16]. Agroforestry has the ability to deliver financial and environmental advantages. Guava (*Psidium guajava* L.) is a common tropical fruit cultivated in many tropical and sub-tropical regions. It belongs to family Myrtaceae and is native of tropical America. In India it is grown in Uttar Pradesh (largest area and production), Bihar, M.P., Maharashtra, A.P. etc. with a total area of 0.13 million hectares. In 2016, India was the largest producer of guavas with 41% of the world total. Guava is a rapidly growing evergreen tree grows up to 3-10 m tall, produces low drop branches from the base and root suckers.

Pearl millet (*Pennisetum glaucum* L.) is the major millet occupying first position among all the millets in India followed by ragi and sorghum. Pearl millet belongs to C_4 cereals are water saving crop as most of the millets mature in 60-90 DAS. More carbon dioxide is utilized by the C_4 cereals and also gets it converted to oxygen. It has low input requirement, high water use efficiency and therefore is environment friendly. Thus pearl millets can help in phasing out climatic uncertainties, reduction in CO_2 concentration and able to contribute in the mitigation of climate change. It is rightly termed as "Nutricereal" as it is a good source of energy, carbohydrate, protein, fat, ash, dietary fibre, iron and zinc (AICRP- Pearl Millet). In India, pearl millet occupies total area of 7.41 million hectare having average production of 10.3 million tonnes with productivity of 1391 kg/ha during 2019-20 (Project coordinator review, 2021) [19]. The most limiting factor for plant productivity is attributed to mineral nutrition (Clark, 1990) [3]. Nitrogen plays an important role in plant metabolism activities as nitrogen helps in formation of many of the component as various vital components such as coenzymes, proteins, chlorophyll, enzymes, nucleic acids, amino acids and a number of hormones. (Yadav and Beniwal 2003) [26]. Out of all the major nutrient elements, nitrogen has great significance in increasing green biomass yield and its quality. Generally, pearl millet is known for its low N requirement crop (Gascho *et al.*, 1995) [5] but many research concluded that by the application of Nitrogen efficiency of production increases.

Nitrogen fertilizer is essential for raising crop production; creating balance among plant nutrients is recognized as key for the maximization of crops yield and growth. (Ciampitti *et al.*, 2013) [2]. The supply of nitrogen antagonistically or synergistically affects the utilization and absorption of different other nutrients (Fageria, 2010) [4].

Crop geometry act as a major factor that governs the production. Suitable crop geometry will enhance the production through proper utilization of nutrients and moisture from below ground and above ground (crop canopy) by the absorption of photosynthetically active radiation (PAR) which results into formation of more photosynthates (Uphoff *et al.*, 2011) [24]. When the plant density is higher, the plant face more completion for various growth factors due to lack of spacing which further reduced the yield per plant. For the enhanced straw and grain yield, wider spacing is superior over the narrower spacing. Moreover, the appropriate crop geometry can assure higher productivity, reduction in seed rate and further healthy stand of the crop in the field. Considering the above facts in view the present investigation is carried out to find the effect of crop geometry and nitrogen management on growth attributes of pearl millet under guava based agri-horti system.

Materials and methods

The field experiment was carried out during kharif season of 2019-20 at the Rajiv Gandhi South Campus Agricultural Research Farm, Barkachha (BHU) Mirzapur, located in the Vindhyan district of Mirzapur ($25^0$10" latitude, $82^0$37" longitude and 427 meters above sea level) UP, India. The soil of the experimental field was sandy clay loam in texture. The initial soil pH (1:2.5, soil and water ratio, Jackson, 1973) [7], Electrical conductivity (1:2 Soil: Water suspension, dSm^{-1} at 25^0C) and soil organic carbon (%, Walkley and Black, 1934) [25] were 5.38, 0.13 and 0.28 respectively. The experimental soil was low in available nitrogen (225.63kg/ha), and medium in phosphorus (20.97kg/ha) and potassium (243.38kg/ha). The experiment was laid out in 11 years old guava which was planted in August 2008 at a spacing of 7 × 7 sq meters. Pearl millet of variety LG-12.81 was sown as intercrop under the alley guava tree. The field experiment was laid out in RBD (factorial) with two factors i.e. crop geometry and nitrogen sources. The treatments were randomized as per the statistical procedure. The experiment consists of a total of 12 treatment combinations that consist of four levels of three crop geometry (45 x 15cm, 40 x 20cm and 30 x 20cm) and 4 levels of nitrogen management (0 kg N ha^{-1}, 100% N by urea, 75% N by urea + 25% N by OM, 50% by urea + 50% by OM) and all the treatments are replicated thrice.

The field was ploughed at optimum tilth and made ready for sowing. The fertilizer doses were calculated and applied to each plot depending on the treatments. For proper maintenance of population of plant a relatively higher seed rate (5 kg ha^{-1}) was used. Seeds were sown by opening furrow with the help of *Kudaal* at different spacing 45x15, 40x20, 30x20 cm as per treatment after the application of fertilizer. Thinning was done to remove extra plants in order to maintain the desired plant spacing and population at 20 DAS (days after sowing). Two intercultural operations such as hoeing and weeding at approx. 50 DAS were conducted.

The biometric observations on growth attributes was taken at an interval of 30 days, i.e. 20^{th}, 50^{th}, 80^{th} DAS and at harvest. The observation was recorded from five tagged plants that were randomly selected from each plot. Observations for growth parameters taken are plant height (cm), dry matter accumulation $plant^{-1}$, number of internode $plant^{-1}$, internode length (cm), number of tillers $plant^{-1}$, Leaf area index, crop growth rate (g m^{-2} day^{-1}) relative growth rate (g m^{-2} day^{-1}).

Crop growth rate (CGR) of a crop is defined as the increase in dry weight of plant material from a unit area per unit time and calculated with the following formula (Radford, 1967) [20].

$$\text{CGR} = \frac{w_2 - w_1}{t_2 - t_1}$$

Where,
W_1 = Total dry weight of plant at time t_1
W_2 = Total dry weight of plant at time t_2
t_1 = Time at first observation
t_2 = Time at second observation

In present experiment, CGR was based on the average of dry matter $plant^{-1}$.

Blackman (1919) [1] pointed out that increase in dry matter of plant is a process of continuous compound interest, when the increments produced in anytime interval are added to the capital for the growth in subsequent period. The rate of increment is called as relative growth rate (RGR). This is calculated by formulas given below and expressed in $g^{-1}g^{-1}$ day^{-1}.

$$\text{RGR} = \frac{log\, e\, w_2 - log\, e\, w_1}{t_2 - t_1}$$

Whereas, Log e – Natural Logarithms, W_1 and W_2 are the weight of total dry matter at time t_1 and t_2 respectively.

Data obtained from various observations were analyzed statistically by adopting the appropriate "Analysis of Variance "method (Gomez and Gomez, 1976) [6].

Results and Discussion

The growth parameters like plant height, dry weight, internode, internode length, Number of tillers/plants, leaf area index, crop growth rate and relative growth rate were significantly affected by application of nitrogen at different stages.

Plant height (cm)

(Table 1) revealed that pearl millet shows the highest plant height recorded in 30×20 cm spacing in crop geometry (176.97 cm). In response with the nitrogen management Maximum height (175.17cm) of the plant was recorded with N_2 (100% RDN by urea) at all stages of growth which was statistically at par with the treatment N_3 (75% RDN by urea + 25% RDN by FYM). However minimum height of the plant was recorded in control (145.56). Crop geometry and nitrogen management interacted significantly on plant height at harvest as presented in the table 1. Maximum plant height (176.97 cm) was recorded with the $S_3 \times N_2$ (30cm × 20cm X 100% RDN by urea) while minimum plant height (143.64 cm) was obtained in the spacing 45cm x 15cm with control (S_1 x N_1). More plant height under optimum spacing might be attributed to effective optimum utilization of nutrients due to less plant competition. Similar result reported by Singh *et al.* (2012) [22], Yadav and jangir (1997) [27] and Kumar *et al.* (2002) [11].

Dry matter accumulation (g $plant^{-1}$)

The data presented in table 1 clearly revealed that dry matter accumulation (g plant^{-1}) of the crop was influenced significantly by different spacing at all growth stages. Maximum dry matter accumulation (35.16 g plant^{-1}) of the plant at harvest was recorded with spacing of 40 cm x 20 cm followed by 45 cm x 15 cm (32.55 g plant^{-1}). With reference to Table 1 it is revealed that there was significant difference in dry matter accumulation of the plant recorded at harvest with different levels of nitrogen. Maximum dry matter accumulation (35.01g plant^{-1}) was recorded with N_2 (100% RDN by urea) at all stages of growth which was statistically at par with the treatment N_4 (50% RDN by urea+50% RDN by OM). However minimum dry matter accumulation was obtained in control (30.03). The Effect of crop geometry in combination with nitrogen level failed to interact significantly. This spacing might have improved photosynthesis and assimilation of carbon dioxide due to better light interception by the leaves to produce higher dry matter production as reported in findings of Mahdi *et al.* (2010) [14] and Patel *et al.* (2010) [18]. The similar result is also supported by Singh *et al.* (2019) [23].

Number of Internode plant^{-1}

As shown in table 1. The number of Internode plant^{-1} was influenced significantly with different spacing at all growth stages. Highest number of internode plant^{-1} (7.31) at harvest was recorded with spacing of 45 cm x 15 cm which was statistically at par with spacing of 40 cm x 20 cm (7.12). However minimum number of internode plant^{-1} (5.94) was recorded with the spacing of 30 cm x 20 cm. The data presented in table 1. Revealed that there was significant difference in number of internode plant^{-1} of the plant recorded at harvest with different levels of nitrogen. Maximum number of internode plant^{-1} (7.59) was recorded with application of 100% RDN by urea at harvest which was statistically at par with the application of 75% RDN by urea+25% RDN by OM (7.48) while minimum number of internode (5.59) was recorded in control. The Effect of crop geometry and nitrogen level failed to interact significantly. This might be due to positive impacts of decomposed organic and additional amount of available nutrients obtained from soil. These findings are also evident with the findings of Kumar (2015) [13].

Internode length (cm)

The data presented in table 1. Clearly revealed that internode length of the crop was influenced significantly with different spacing at all growth stages. Maximum internode length of the plant (17.83 cm) at harvest was recorded with spacing of 40 cm x 20 cm which was statistically at par with spacing of 45 cm x 15 cm (16.88 cm). However minimum internode length of plant was recorded with the spacing of 30 cm x 20 cm (14.95 cm). With reference to Table 1. it is revealed that there was significant difference in Internode length of the plant recorded at harvest with different levels of nitrogen. Maximum internode length (19.45 cm) of the plant was recorded with the application of 100% RDN by urea at harvest followed by the application of 50% RDN by urea+50% RDN by OM (16.16 cm). However, the minimum internode length of plant is obtained in control (14.28 cm). Effect of crop geometry and nitrogen level failed to interact significantly. This might be due to positive impacts of decomposed organic and additional amount of available nutrients obtained from soil. These findings are also evident with the findings of Kumar (2015) [13].

Number of tillers per plant

The data presented in table 1. Clearly revealed that number of tillers plant^{-1} of the crop was influenced significantly only at harvest. Maximum number of tillers plant^{-1} (1.64) at harvest was recorded with spacing of 40 cm x 20 cm which is followed by spacing of 45 cm x 15 cm (1.61). However, the minimum number of tillers plant^{-1} (1.39) was recorded with the spacing of 30 cm x 20 cm. With reference to table 1. it is revealed that difference in number of tillers plant^{-1} recorded at harvest was found non-significant with different levels of nitrogen. However maximum number of tillers plant^{-1} (1.59) was recorded with the application of 100% RDN by urea at harvest followed by 50%RDN by urea+50% RDN by OM while minimum number of tillers plant^{-1} was observed in control. Effect of crop geometry and nitrogen level failed to interact significantly. The reduction in number of tiller treatment may be due to the reduction in number of buds which caused tiller formation. These findings are in harmony with those obtained by Koraiem *et al.* (1983) [10].

Leaf area index

The data presented in table 1. Clearly revealed that leaf area index of the crop was influenced significantly by different spacing at all growth stages. Maximum leaf area index of the plant (2.03cm) at harvest was recorded with spacing of 40 cm x 20 cm which is followed by 45cm x 15 cm (1.76cm). However minimum leaf area index of the plant was recorded with the spacing of 30 cm x 20 cm (1.71cm). With reference to Table 1. it is revealed that there was significant difference in leaf area index of the plant recorded at harvest with different levels of nitrogen. Maximum leaf area index (2.14 cm) of the plant was recorded with N_2 (100% RDN by urea) at harvest which was followed by the treatment N_3 (75% RDN by urea+25% RDN by OM) and N_4 (50% RDN by urea+50% RDN by OM) respectively. However, the minimum leaf area index was observed with control. Effect of crop geometry and nitrogen level interacted significantly as presented in the table 1. Maximum leaf area index (2.14 cm) was recorded with the application of nitrogen level N_2 (100% RDN by urea) in combination with spacing 40 cm x 20 cm. while minimum Leaf area index (1.71 cm) was obtained in the spacing 30cm x 20 cm with control. These increments in LAI as nitrogen fertilization rates increased may be regarded to the increase in leaf area or/and number of leaves per unit area (Table 1) with increasing nitrogen fertilization rates. These trends are in agreement with those obtained by Paciullo *et al.* (1998) [15], Jinxing *et al.* (1998) [8] and Kathju *et al.* (2001) [9].

Table 1: Effect of crop geometry and nitrogen management on growth attributes of pearl millet under guava based agri-horti system.

Treatments	Plant height (cm)	Dry matter (g/plant)	Internode (no./plant)	Internode length (cm)	Number of tillers/plant	Leaf area index
Crop geometry (cm)						
45x15	143.64	32.55	7.31	16.88	1.61	1.76
40x20	167.66	35.16	7.12	17.83	1.64	2.03
30x20	176.97	30.95	5.94	14.95	1.39	1.71

S Em±	3.53	0.86	0.29	0.56	0.08	0.07
CD (P=0.05)	10.35	2.53	0.86	1.63	0.22	0.20
Nitrogen Management(kg ha^{-1})						
0 kg RDN ha^{-1}	145.56	30.03	5.59	14.28	1.52	1.59
100% RDN by urea	175.17	35.01	7.59	19.54	1.59	2.14
75% RDN by urea + 25% RDN by OM	167.11	31.86	7.48	16.16	1.52	1.83
50% RDN by urea + 50% RDN by OM	163.16	34.64	6.49	16.23	1.56	1.78
S Em±	4.07	1.00	0.34	0.64	0.09	0.08
CD(P=0.05)	11.95	2.92	0.99	1.88	0.26	0.23
Interaction	S	NS	NS	NS	NS	S

100% RDN= Recommended Dose of Nitrogen = 80 kg N/ha; OM= Organic matter

Crop growth rate (g/m^2/day)

The data presented in table 2. Clearly revealed that crop growth rate of the plant was significantly affected by different spacing at 20-50 DAS and 80-harvest while at 0-20 DAS and 50-80 DAS the effect of spacing was found non-significant. The highest crop growth rate of the plant (0.92) at 20-50days and (0.21) at 80-harvest was recorded with spacing of 40 cm x 20 cm is significantly superior to other treatment. However, the lowest crop growth rate was recorded with the spacing of 30 cm x 20 cm (0.71) at 20-50 DAS and (0.16) at 80-harvest. The data showed that the application of 100% RDN by urea recorded maximum (0.90) at 20-50 DAS, (0.33) at 50-80DAS and (0.22) at 80-harvest which was statistically at par with the treatment N_3 (75% urea + 25% OM) at 20-50 DAS and N_4 (50%urea+50% OM) at 50-80DAS and 80-harvest. Effect of crop geometry and nitrogen level failed to interact significantly.

Relative growth rate (g/m^2/day)

The data presented in table 2. Clearly revealed that relative growth rate of the crop was significantly affected by different spacing at all growth stages. Maximum relative growth rate of the plant (2.49) at 20-50DAS, (0.86) at 50-80DAS and (0.65) at 80-harvest was recorded with spacing of 40 cm x 20 cm which was statistically at par with spacing 30cm x 20 cm at 50-80DAS and with 45cm x 15cm at 80-harvest. However minimum relative growth rate of the plant was recorded with the spacing of 30cm x 20 cm (1.92) at 20-50 DAS and (0.51) at 80-harvest. While at 50-80 DAS minimum (0.65) was obtained with the spacing 45cm x 15cm. the data presented in Table 2. Showed that different nitrogen level significantly affected the relative growth rate at all stages. The application of nitrogen level N_2 (100% RDN by urea) recorded maximum relative growth rate (2.43) at 20-50 DAS, (0.92) at 50-80 DAS and (0.65) at 80-harvest which was statistically at par with the treatment N_3 (75%urea+25%OM) at 20-50 DAS and with control and N_4 (50%urea+50%OM) at 50-80DAS and 80-harvest. Effect of crop geometry and nitrogen level failed to interact significantly. This could be due to a smaller number of plants per meter square which resulted in less dry matter production but more utilization of nutrients and more growth rate due to less plant density. Improvement in the overall growth of pearl millet have been also stated by Rana *et al.* (2009) [21], Kumar *et al.* (2004) [12], Yadav and Jangir (1997) [27] and Pandey *et al.* (1998) [17].

Table 2: Effect of crop geometry and nitrogen management on CGR and RGR of pearl millet under guava based agri-horti system.

Treatments	Crop growth rate (g/m^2/day)				Relative growth rate (g/m^2/day)		
	0-20 DAS	20-50 DAS	50-80 DAS	80-Harvest	20-50 DAS	50-80 DAS	80-Harvest
Crop geometry (cm)							
45x15	0.01	0.83	0.25	0.17	2.25	0.65	0.57
40x20	0.01	0.92	0.30	0.21	2.49	0.86	0.65
30x20	0.01	0.71	0.27	0.16	1.92	0.85	0.51
S Em±	0.00	0.03	0.02	0.01	0.08	0.05	0.04
CD (P=0.05)	0.00	0.08	0.05	0.03	0.23	0.15	0.11
Nitrogen Management (kg ha^{-1})							
0 kg RDN ha^{-1}	0.01	0.72	0.27	0.17	1.94	0.79	0.55
100% RDN by urea	0.01	0.90	0.33	0.22	2.43	0.92	0.65
75% RDN by urea + 25% RDN by OM	0.01	0.87	0.22	0.16	2.36	0.69	0.48
50% RDN by urea + 50% RDN by OM	0.01	0.79	0.28	0.19	2.14	0.75	0.63
S Em±	0.00	0.03	0.02	0.01	0.09	0.06	0.04
CD(P=0.05)	0.00	0.10	0.06	0.03	0.26	0.17	0.12
Interaction	NS	NS	NS	NS	NS	NS	NS

100% RDN= Recommended Dose of Nitrogen = 80 kg N/ha; OM= Organic matter

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