PLANTING GEOMETRY-INDUCED ALTERATION IN WEED INFESTATION, GROWTH AND YIELD OF PUDDLED RICE

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ABSTRACT

Transplanted rice generally produces better yield than direct seeded rice if managed properly. The present study was conducted in order to explore the effects of varying planting geometries under weedy and weed free conditions in puddled rice. Three different planting geometries viz; 20cm × 20cm, 20cm × 15cm and 15cm × 15cm were evaluated under weedy and weed free environments. The experiment was laid out in a randomized complete block design (RCBD) with factorial arrangement and replicated thrice. Data were collected pertaining to weeds infestation, growth and yield related attributes of rice. The results revealed that maximum weed suppression was observed in closest plant spacing (15cm × 15cm) in case of weedy treatments 20 and 40 days after transplanting (DAT), while widest plant spacing (20cm × 20cm) proved effective regarding yield and yield related attributes. Statistically maximum leaf area index (LAI) of 9.06, crop growth rate (CGR) of 3.96 g m^{-2} d^{-1} and leaf area duration (LAD) of 109.28 days, paddy and biological yield (4.14 and 15.42 t ha^{-1}), respectively were recorded in widest spacing of 20cm × 20cm. Moreover, improved growth and yield related parameters of rice were recorded under weed free conditions as compared to weedy plots.

Key words: Growth, planting geometry, transplanted rice, weeds, yield.

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INTRODUCTION

More than half of the world population depends on rice as it is the staple food of many developed and developing countries around the globe (Chauhan *et al.,* 2011). Approximately 149 million hectare

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area is under rice cultivation all over the world with an annual production of 600 million tones and has 2nd highest rank in global production, after maize (Shaikh *et al.,* 2003). In Pakistan, it ranks 3rd in area-wise order after wheat and cotton. Total production of the rice in country is 5541 thousand tones which meet the food requirement of the country and excess is exported to foreign markets to earn foreign exchange (Govt. of Pakistan, 2012-13). Average paddy yield of rice in Pakistan is 2398 kg ha^{-1} which is very low as compared to other developed or even developing countries like India and China where average rice production is 6341 and 3208 kg ha^{-1},respectively (FAO, 2007). It is cultivated traditionally in flooded conditions mostly for availability of irrigation water and effective weed control (Bouman, 2003). Moreover, both direct seeding and transplanting has their own advantages and disadvantages but and efficient weed management in puddle rice provides higher economic returns than direct seeded rice (Hossain *et al.,* 2002). Important causes of low yield of rice are non-availability of skilled labor for transplanting, high amount of required inputs, water shortage, weed infestation, sub-optimal plant population and poor marketing system (Baloch *et al.,* 2004). Normally the decrease in yield in rice due to weeds infestation ranges between 15-20%, yet under severe conditions the losses may raise up to 50% or higher, depending upon the types, species, pressure and intensity of weeds (Chauhan, 2013).

Planting density of a crop determines solar radiation interception, crop canopy coverage and total dry matter accumulation (Anwar *et al.,* 2011). However, several studies reveal that closer planting may cause mutual shading and may lead to intra-specific competition that intensify various problems like lodging (Bond *at al.,* 2005), insect pest infestation (Tan *et al.,* 2000) and even rat injury (Castin and Moody, 1989). Therefore, planting geometry and plant spacing should be optimized by keeping in mind different aspects of cropping management techniques. Optimum plant spacing ensures plants to grow properly both in their above and underground parts through different utilization of solar radiation and nutrients. The optimum plant density depends upon different factors such as plant characteristics, planting time, plant size, growth period, soil fertility, sun shine, available moisture, planting pattern and weed infestation (Shirtliffe and Johnston, 2002).

Moreover, Das *et al.* (1998) reported that plant population and number of seedlings per hill may influence stand geometry and ultimate yield of transplanted rice and further concluded that narrow plant spacing and more number of seedlings per hill has been found most effective to compensate the yield loss because of high planting density and tiller population per unit area. The plants largely depend on solar radiation, temperature, available moisture and soil fertility for their growth and nutrition requirements. A dense population of crops may have limitations in the maximum availability of these factors. It is, therefore, necessary to determine the optimum density of plants population per area unit for obtaining higher yields (Baloch *et al.*, 2002).

So, planting arrangements and variable plant geometry are the two important agronomic practices which can cause substantial effect on the stand establishment of the transplanted rice, and hence its ultimate yield. The planting geometry can further persuade variations through modification in the accomplishment of phenological phases and ultimately the development of canopy cover. The objective of this study was to find optimum plant spacing which is suitable for plant growth and discourage weed infestation.

MATERIALS AND METHODS

Experimental site

Effect of planting geometry on growth and yield of transplanted rice was evaluated in a field experiment during kharif season, 2012 at Agronomic Research Area, Department of Agronomy, University of Agriculture, Faisalabad (31.25°N latitude, 73.09°E longitude, altitude 184 m). The soil of experimental site belongs to Lyallpur soil series (Aridisol-fine-silty, mixed, hyperthermic Ustalfic, Haplargid in USDA classification and Haplic Yermosols in FAO classification).

Experimental treatments

The experiment was laid out in randomized complete block design (RCBD) and replicated thrice. The experimental treatments comprised of three different plant spacings viz; G_1 (20 cm × 20 cm), G_2 (20 cm × 15 cm) and G_3 (15 cm × 15 cm). Weed density was controlled by early post emergence herbicide Penoxulam @ 15 mL a.i. ha^{-1} followed by hand weeding in weed free treatments. Whereas, 33 days old seedlings of fine rice were transplanted in proposed geometries manually in all experimental units.

Crop husbandry

Nursery of fine rice cultivar 'Super Basmati' was sown on 2^{nd}June and transplanted in the field on 5^{th} July where puddled conditions were created. The seed rate for raising nursery was used about 4 kg per acre. Nutrient requirement of the crop was compensated by the application of 125 kg ha^{-1} N, 55 kg ha^{-1} P_2O_5 and 40 kg ha^{-1} K_2O. Whole of the phosphorus and potash and half of the nitrogen were applied at the time of transplanting while the remaining half was applied in two equal splits after 25 and 45 days after transplanting. Plant protection measures were taken, as needed, to avoid confounding effect of competition with insect and/or disease injury.

Data collection

Weed density was recorded from two randomly placed quadrates (0.25 m^2) in an experimental plot then converted to m^2. In order to get dry weight, weed samples were sun-dried for four days and then placed in an oven at 70 ºC for 48 h till constant weight. Different intercultural operations and plant protection measures were conducted following standard procedures. Crop was harvested, tied into bundles to their respective plots and was manually threshed to determine grain yield as well as straw and reported on t ha^{-1} basis. Leaf area index (LAI), crop growth rate (CGR) and leaf area duration (LAD) were computed by the following formulas:

$$LAI = Leaf\ area / Land\ area$$

$$CGR = (W_2 - W_1) / (t_2 - t_1)$$

Where

W_1= Total dry matter at the first harvest

W_2 = Total dry matter at the second harvest

t_1 = Date of observation of first dry matter

t_2= Date of observation of second dry matter

$$LAD = (LAI_1 + LAI_2)(t_2 - t_1)/ 2$$

LAI_1 = Leaf area index at first harvest

LAI_2 = Leaf area index at second harvest

t_2 = Date of observation at first harvest

t_1= Date of observation at second harvest

Data analysis

Fisher's analysis of variance technique was used to analyze the data and least significant difference (LSD) test at 0.05 probability was employed to compare the treatments' means.

RESULTS AND DISCUSSION

Floristic composition of weeds at experimental site

The experimental site was infested by 10 various types of weed species which includes five grasses (*Echinochloa colona*, *Echinochloa cruss-galli, Cynodon dactylon, Dactyloctenium aegyptium* and *Paspalam distichum*), two broadleaved (*Conyza stricta* and *Alternanthera philoxeroides*) and three sedges (*Cyperus rotundus, Cyperus iria,* and *Cyperus difformis*). Moreover, *Echinochloa colona* and *Cyperus rotundus* were found dominant all over the season.

Density and dry matter of weeds

Weed density and dry matter varied significantly due to plant spacing and plant population. The widest plant spacing recorded the highest weed density and dry matter of weeds. For example, weed density at spacing of 20 cm × 20 cm at 20 and 40 DAT (days after transplanting) were 29.33 and 36 m^{-2}, respectively whereas lowest weed density (16 and 22.67 m^{-2}) was recorded in closest plant spacing (15 cm × 15 cm) at 20 and 40 DAT of rice. Similar trend was noted in the dry matter accumulation of weeds where widest spacing led to maximum (13.15 and 16.37 g m^{-2}) weeds dry matter while minimum (7.68 and 11.41 g m^{-2}) was recorded in the narrowest plant spacing at both stages. The environmental conditions and micro-climate of experimental site was favorable to various kinds of weed growth and development. The alteration in weed pressure encounter in terms of density and dry matter of weeds and also in relative proportion of different kind of weeds might be due to different rates of canopy closure and, partially due to intrinsic weed flora of the experimental site. Highest weed density and dry weight of weeds in widest plant spacing might be due to more number of weeds and availability of suitable space to grow and flourish to its maximum number and face minimum weed-crop competition. Light and nutrient availability in wider plant spacing provide a chance to weeds along with the crop to grow easily as compared to narrow plant spacing where chances of weeds to grow were less due to less space availability and high crop-weed competition. Reduced weed density in closer spacing has been reported by many investigators (Shinggu *et al.,* 2009; Anwar *et al.,* 2011). Moreover, chemical weed control is an easy, quick and economical strategy of weed control and reduced the weed density and biomass significantly over unweeded check (Rao and Ratnam, 2010).Further, in another experiment, above ground weed biomass was found lower in narrow row maize as compared to wide row maize (Acciares and Zuluaga, 2006).

Leaf area index (LAI)

LAI is considered a major physiological determinant for the crop yield. Planting geometry substantially affected the LAI of crop under both weedy and weed free condition. Moreover, highest LAI was attained in widest spacing and lowest one with closest spacing both under weedy and weed free conditions. Moreover, in weedy treatments LAI was found considerably lower as compared to weed free treatments. Maximum LAI was recorded in 20 cm × 20 cm (7.98) followed by 20 cm × 15 cm and 15 cm × 15 cm where LAI (7.76 and 7.19) were recorded, respectively. Weed infestation reduced the LAI of the crop significantly. The LAI continuously increased up to 60 DAT and then it gradually declined towards maturity due to leaf senescence. The improved leaf area index in spacing 20 cm × 20 cm might be due to reduced intra plant competition, maximum light interception and provision of a weed free environment where weeds are discouraged to grow after the application of spray. Closed spacing reduced the leaf area index. This might be due to an increased intra plant competition. Ali *et al.* (2008) found an increase in all growth parameters except LAI in closest spacing (15 × 15 cm) under his study.

Crop growth rate (CGR)

CGR is the accumulative growth rate of the crop all over the season. CGR is affected significantly by different planting geometries under both conditions (weedy and weed free). In our study, maximum CGR was attained in widest plant spacing while closest spacing resulted in minimum growth rate of crop under both conditions weedy and weed free. It was further elucidated that under weed free conditions CGR was noticeably higher as compare to weedy treatments. Highest CGR was recorded in 20 cm × 20 cm (3.96 g m^{-2} d^{-1}) followed by 20 cm × 15 cm and 15 cm × 15 cm where crop growth rate (3.40 and 3.06g m^{-2} d^{-1}) were recorded, respectively. Poor growth rate was observed in those experimental plots which were infested by weeds. Moreover, CGR increased up to 60 DAT continuously and then it steadily turndown towards maturity of the crop. Lowest CGR was found in the closest spacing which might be to due maximum intra plant competition for acquisition of resources and ultimately crop growth rate declined. Islam *et al.* (2000) also stated the same results and reported that maximum crop growth rate can be achieved when there is no or lesser weed competition and adequate resource availability to the crop. Moreover, weed infestation minimizes the crop growth rate adversely.

Leaf area duration (LAD)

Leaf area duration is an important yield determining attribute which plays a crucial role growth rate of a crop. LAD largely depends upon leaf area index and also influenced by the prevailing environmental conditions. Planting geometries influenced the LAD significantly under weedy and weed free conditions. Maximum leaf area duration (109.58 days) was computed in 20 cm × 20 cm plant spacing under weed free condition which was followed by 20 cm × 15 cm and 15 cm × 15 cm where LAD was 106.28 and 97.68 days, respectively. Moreover, presence of weeds in weedy plots and intra-plant competition in narrowest spacing abundantly reduced the leaf area duration due to poor leaf development. The reason of minimum leaf area duration in weedy plots might be due to the presence of weeds and their competition with crop throughout the growing season. The results of present study regarding this attribute are in contradictory with the previous findings of Rasool *et al.* (2012) who found maximum LAD where transplanting of rice was done closely.

Plant height and tillering ability

Planting geometry affected the plant height and tillering capacity of the rice crop significantly. Statistically, maximum plant height (120.92 cm), number of total tillers (18.53) and productive tillers (15.12) were recorded in widest spacing which differed considerably from other two spacings under study. However, closest spacing was found at par with the 20 cm × 15 cm pertaining to plant height. Moreover, an interactive affect was also observed between weed control treatments and productive tillers per hill. Maximum productive tillers were found in widest plant spacing under weed free conditions while minimum was obtained from closest spacing under weedy treatments. It was also observed that closest spacing proved inefficient regarding tillering ability and provided lowest number of total tillers and productive tillers as well. Moreover, weed free conditions proved most effective and better regarding plant height and tillering ability as compared to weedy conditions and differed significantly. These results are in consistence with the conclusions of Ayub and Tanveer (1990) and Ehsanullah *et al.* (2007) who reported 20 × 20 cm planting distance is better for rice growth and production of maximum tillers. Tari *et al.* (2009) also reported the same results after conducting research on planting geometry in rice.

Yield and yield related attributes

Planting geometries and weed control treatments affected the yield and its related attributes significantly. Among different plant spacings maximum plant height (120.92 cm), total number of tillers (18.53) and productive tillers per hill (15.12) was recorded in 20 cm × 20 cm while weed free conditions also influenced plant height, total and productive tillers per hill significantly. Highest number of filled grains per panicle (111.34), 1000-grain weight (19.99 g), paddy as well as biological yield (4.14 and 15.42 t ha^{-1}) was obtained with widest spacing (20 cm × 20 cm) and lowest was recorded in closest (15 cm × 15 cm). Moreover, closest spacing was found statistically at par with the 20 cm × 15 cm regarding paddy and biological yield. Weed free conditions also affected the yield and yield related characters which significantly differed from weedy conditions. Results showed that rice yield loss varies with varied planting geometry. Increased yield loss difference with decreased spacing might be attributed to the increased intra plant competition, dense canopy cover and probably due to shading effect. More number of plants per unit area needs more resources to survive to minimize the intra-plant competition otherwise nutrient starvation and sub-optimal availability of light and space may lead to poor stand establishment and panicle sterility which will ultimately affect the economic yield of rice. Patel (1999) also recorded the maximum yield and yield related attributes in rice transplanted at 20cm × 20cm planting distance as compared to narrower spacing than this.

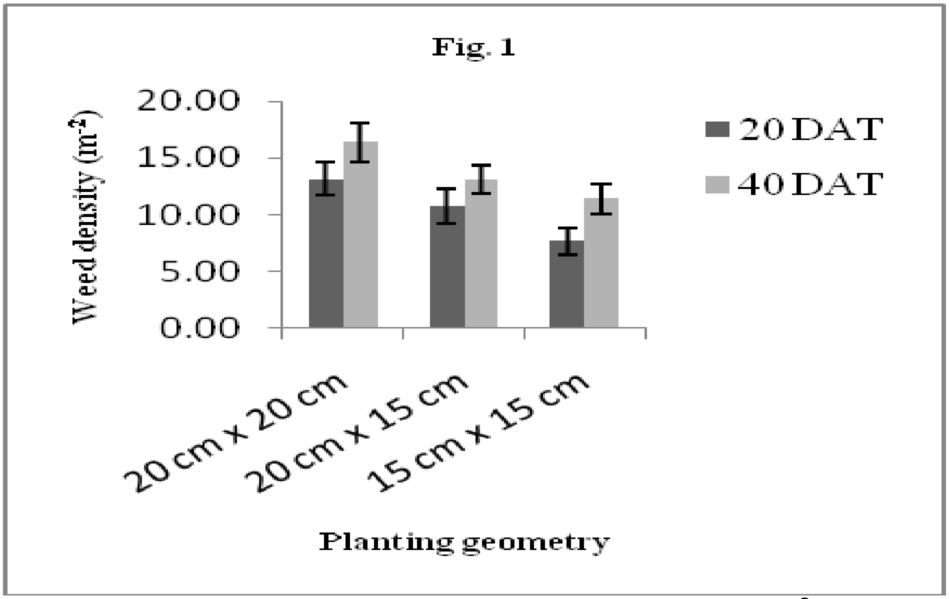

Figure 1. Effect of planting geometry on weed density (m^{-2}) in weedy treatments at 20 and 40 days after transplanting (DAT)

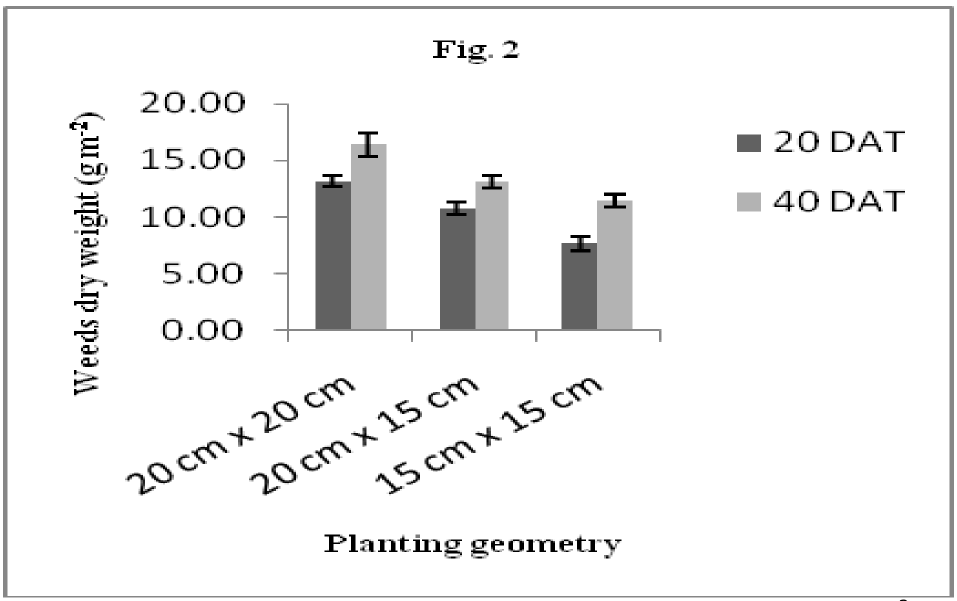

Figure 2. Effect of planting geometry on weed dry matter (g m^{-2}) in weedy treatments at 20 and 40 days after transplanting (DAT)

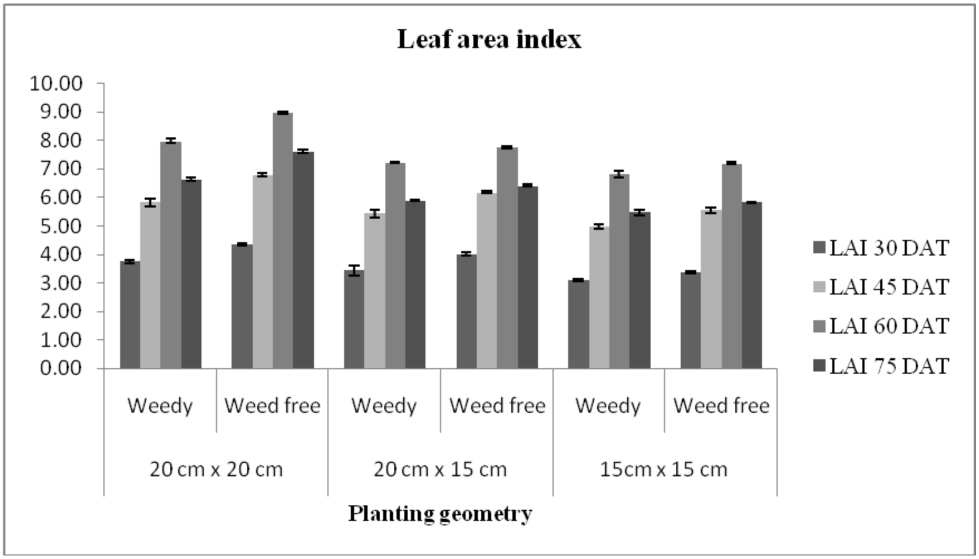

Figure 3. Effect of planting geometry and weed competition on leaf area index of puddle rice at various growth stages.

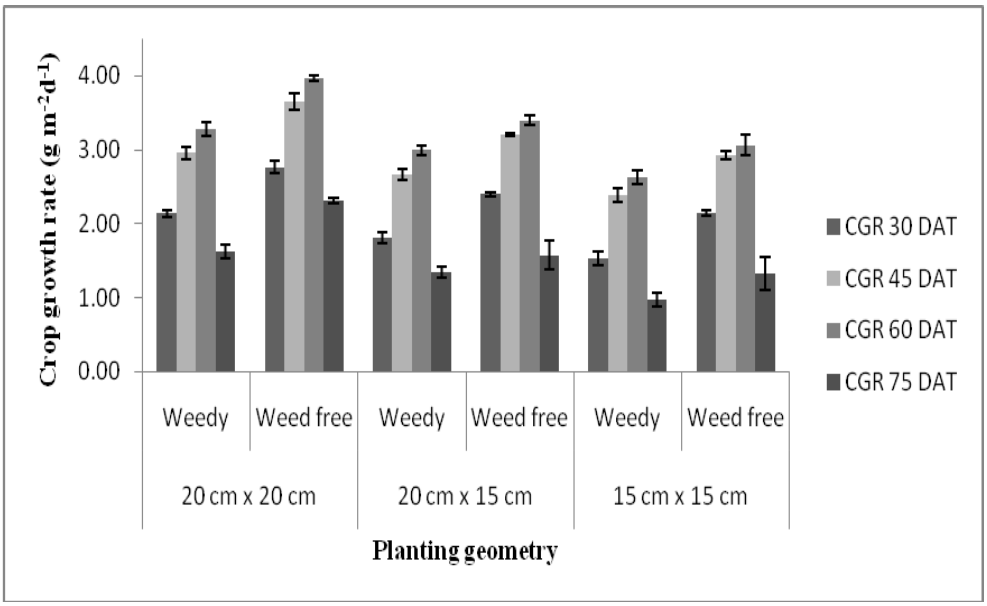

Figure 4. Effect of planting geometry and weed competition on crop growth rate of puddle rice at various growth stages.

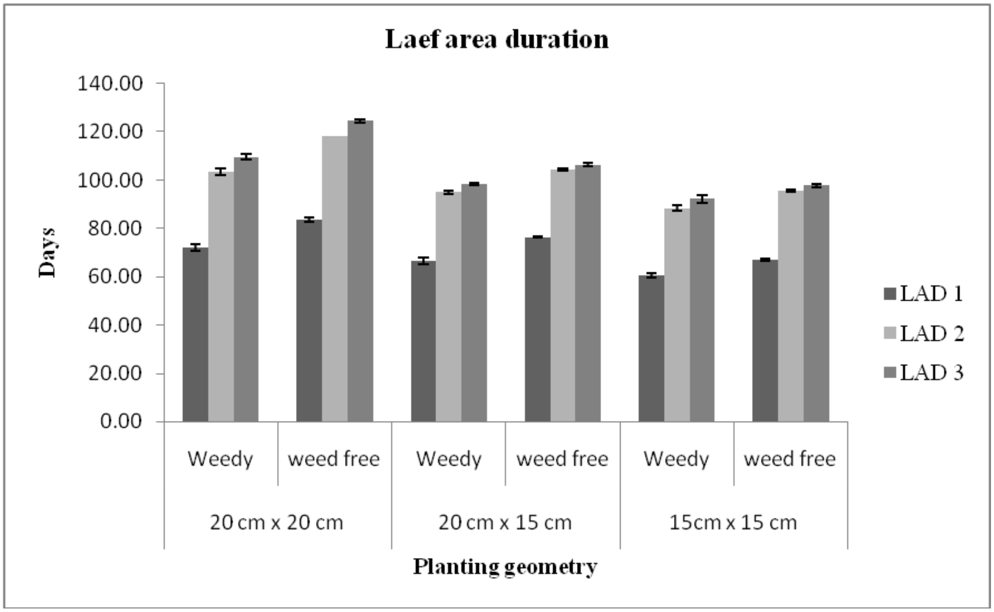

Figure 5. Effect of planting geometry and weed competition on leaf area duration of puddle rice at various growth stages.

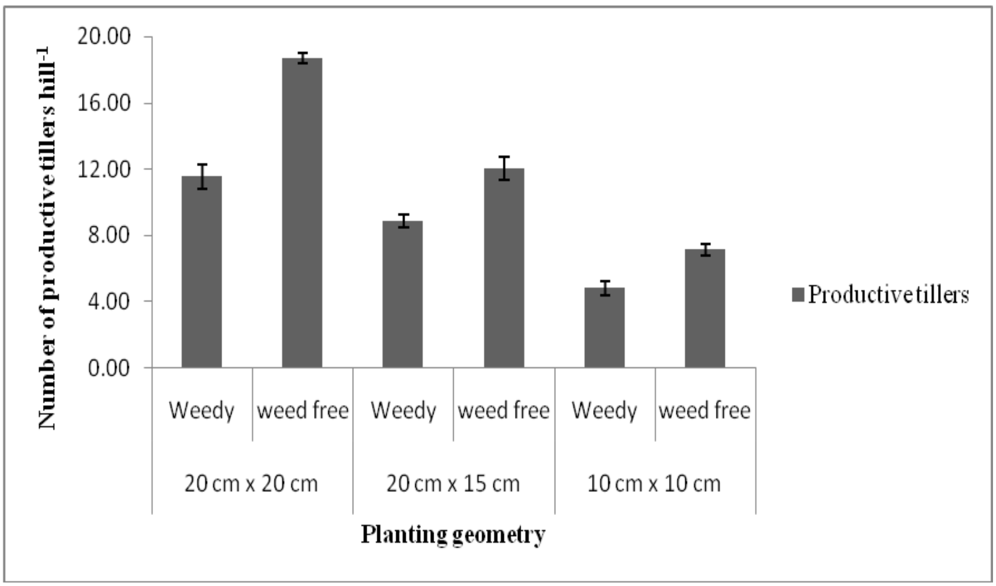

Figure 6. Interactive effect of planting geometry and weed control treatments on productive tillers per hill

Table-1. Effect of planting geometries and weed competition on yield and yield related attributes of transplanted rice

Treatments / Planting geometry	Plant height (cm)	Total tillers $hill^{-1}$	Prod. tillers $hill^{-1}$	Filled grains $panicle^{-1}$	1000 grain weight (g)	Paddy yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)
20 × 20 cm	120.92a	18.53a	15.12a	109.88a	19.99a	4.04a	15.42a
20 × 15 cm	116.02b	13.00b	10.45b	100.93b	17.53b	3.45b	13.50b
15 × 15 cm	112.93b	8.05c	5.95c	92.28c	15.55c	3.25b	12.38b
LSD (0.05)	**3.10**	**1.31**	**1.24**	**3.94**	**1.52**	**0.48**	**1.42**
Weed control							
Weedy	110.84b	10.74b	8.40b	90.72b	15.54b	3.03b	12.22b
Weed free	122.40a	15.64a	12.61a	111.34a	19.84a	4.14a	15.31a
LSD (0.05)	**2.53**	**1.07**	**1.01**	**3.22**	**1.24**	**0.39**	**1.16**

Means within a column with the same letter are not significantly different at p = 0.05 (LSD)

CONCLUSION

At the end, it might be concluded that closer planting distance did not provide an increased yield as was expected, which might be due to nutrient starvation because only recommended dose of fertilizer was applied in all planting geometries whereas 20 cm × 15 cm and 15 cm × 15 cm spacing were too close to be feed with the same fertilizer dose as for recommended planting distance (22.5 $cm^{2)}$ whereas weed free conditions encouraged rice growth and yield considerably. So, it is necessary to keep the weed population low to get maximum returns. Further, weed management through varying planting geometries might be a viable tool for long term strategy of weed control.

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