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AGRONOMY

AGRONOMIC AND ECONOMIC EVALUATION OF VARIOUS PLANTING GEOMETRIES OF RICE (*ORYZA SATIVA* L.) VARIETY "BASMATI 515"

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ABSTRACT

Present study was conducted at Pakistan Agriculture Research Council (PARC) Farm, Kala Shah Kaku in 2014. Rice seedlings were transplanted in different planting geometries with line to line and plant to plant distances of 25×10, 30×10, 20×15, 25×15, 20×20, 30×15, 25×20 22.5×22.5 and 25×25 cm in randomized complete block design (RCBD) with three replications. Results revealed higher number of tillers with closer plant spacing that ultimately exhibited greater number of panicles (309.3 to 275.5 m^{-2}) in plant spacing ranging from 25×10 to 30x15 cm. Higher paddy yields (3.81 to 3.61 t ha^{-1}) and straw yields (14.8 to 13.5 t ha^{-1}) were also recorded from the same treatments (25×10 to 20×20 cm). The highest net benefit (Rs.105149.72 ha^{-1}) was recorded in 20×20 cm spacing treatment while the lowest (Rs.90614.55 ha^{-1}) was achieved from the widest spacing (25x25 cm) treatment. The maximum net benefit and a viable marginal rate of return (102%) was observed from 20×20 cm plant spacing. It can be concluded from results that Basmati 515 should be transplanted in a planting geometry of 20×20 cm to achieve the maximum grain yield with higher economic returns.

KEYWORDS: basmati 515, grain yield; plant geometry; rice; economic; Pakistan.

INTRODUCTION

Rice (*Oryza sativa* L.) is the second most important basic food crop and export item of Pakistan. It is cultivated over 2.9 million hectares area that gives 7.45 million tonnes production. National average paddy yield is 2568 kg ha^{-1} that is quite low as compared to advanced rice producing countries of the world (GOP, 2019). The factors limiting rice productivity in Pakistan include low yielding rice varieties, imbalanced crop nutrition, inadequate plant protection and most importantly the sub-optimal plant population in the field. Rice transplanting is mainly carried out manually through labor in Pakistan (Aslam *et al.,* 2008) that usually resulted in low plant population.

Rice varieties exhibit variable tillering potential (Hussain *et al.,* 2014) that determine the planting geometry to be adopted to get optimum number of hills per m^{-2} for optimum yield. Rice plant population also affects the productive tillers per unit area and eventually affects crop yields (Awan *et al.,* 2008; Kumar *et al.,* 2002; Rasool *et al.,* 2012), that relies on plant genetic potential, transplanting date, radiation intensity, moisture and weeds species present (Shirtliffe and Johnston 2002). Plant's physiological processes also have a direct bearing on spacing maintained among them (Oad *et al.,* 2001). Optimum planting distance allows plant to efficiently utilize light and nutrients for maximum yield (Mohaddesi *et al.,* 2011). With systematic geometrical arrangement of plants, maximum light penetration occurs within crop canopy and lesser interplant leaf shading effect that results higher photosynthetic rates (Anwar *et al.,* 2011). Dense plant population increases competition for water, nutrients, light and space and produces thin plant stems that are prone to crop lodging (Baloch *et al.,* 2002; Bond *et al.,* 2005). It also increases leaf area index (LAI) beyond critical LAI, which may become the cause of lower yield instead of increasing the yield. Number of panicles per m^2, biological and paddy yield of rice increased in response to rising planting density (Sabeti and Kenorsari, 2006). Amin *et al*., (2004) noted that more number of panicles m^{-2} and straw yield of IR-6 variety of rice were recorded with closer plant population (20×10 cm) compared to that obtained with wider one (20×20 cm). Rice variety Hashemi attained a higher grain yield at plant spacing of 15×15 cm as compared to plant spacing 20×20 cm and 25×25 cm (Bozorgi *et al.,* 2011). Salahuddin *et al*. (2009) got higher grain yield of Aman rice from 25×10 cm spaced plants than 25×15 cm and 25×20 cm geometries. Ashraf *et al*. (2014) reported that super basmati transplanted at spacing of 20×20 cm produced higher biological (15.42 t ha^{-1}) and paddy (4.14 t ha-1) yields than 20×15 cm and 15×15 cm plant spacings. Similarly, Limochi (2013) demonstrated that 20×20 cm spacing gave maximum paddy yield significantly higher from those recorded with 15×15 cm and 25×25 cm. Rasool *et al*. (2013) recorded more plant height, tillers m^{-2}, LAI, plant biomass and paddy yield from plots planted at spacing 15×15 cm in comparison with those planted at planting geometries of 15×20 cm and 20×20 cm.

Basmati 515 is a new fine rice variety having lower tillering potential compared to super basmati existing fine rice variety popular among growers. Transplanting at traditionally used spacing of 22.5×22.5 cm needs to be re-examined due to less tillering potential of this new variety. A very little is known about response of Basmati 515 to different plant spacings in terms of optimum plant population, productive tiller per unit area, and achieving higher yields with highest economic returns. It is imperative to determine optimum planting geometry of new variety to get optimum growth and yield potential. The current study was therefore designed for agronomic and economic evaluation of Basmati 515 at different planting geometries to find out most suitable planting geometry for getting optimum grain yield under agro-ecological conditions of traditional rice growing areas of Punjab, Pakistan.

MATERIALS AND METHODS

Field experiments were conducted during summer seasons of the years 2013 and 2014 at PARC farm, Kala Shah Kaku, Lahore along with 31°43'18" Northern Latitude and 74°16'2" Eastern Longitude. The physicochemical analysis of experiment soil showed that it was clay loam having 8.3 pH and 2.5 dS/m electrical conductivity. The organic matter, available K and P contents were 0.84%, 89 ppm and 4.7 ppm, respectively. The experiments were laid out in randomized complete block design and each treatment was replicated thrice. Age of nursery at the time of transplanting was 35 days. Two seedlings per hill were transplanted manually in a puddled field during second week of July during each year. Planting geometries in sequence of increasing area from 250 to 625 cm^2 per hill[1] included 25×10 cm, 30×10 cm, 20×15 cm, 25×15 cm, 20×20 cm, 30×15 cm, 25×20 cm, 22.5×22.5 cm, and 25×25 cm line to line and plant to plant spacings. Rice nursery was raised by broadcasting of sprouted seeds on puddled nursery beds. Nitrogen, P and K fertilizers were applied @134-86-50 kg ha^{-1}, respectively. Whole P and K along with 1/3rd N were applied at transplanting while remaining N was applied in two equal splits viz., 30 days after transplanting (DAT) and 50 DAT. Five DAT, pre-emergence herbicide and 15 DAT, zinc sulphate (35%) @ 12.5 kg ha^{-1} were applied. To control insect-pest and diseases, recommended plant protection measures were adopted.

During both the years of study, data pertaining to plant height and number of tillers per plant from 10 randomly selected plants per plot were collected with 20 days interval from transplanting to harvesting (20, 40, 60, 80, and 120 DAT). However, yield and yield related traits were measured at crop harvesting (13-11-2013 and 14-11-2014). Data of both the years showed similar trend therefore pooled and two-year average data of all parameters were analyzed according to method described by Fisher's analysis of variance and then least significant difference test at 5% probability level was employed to compare treatment means (Montogomery, 2001). Economic and marginal analyses were performed to find out the most cost-effective treatment (planting geometry). Marginal cost, marginal benefit and marginal rate of return (MRR) were calculated from their prescribed formulae (Byerlee, 1988).

RESULTS AND DISCUSSION

Plant Height (cm)

Plant height of rice in all spacing treatments followed a linear increasing trend up to 20 days after transplanting (DAT), lag phase up to 40 DAT then again steep linear enhancement up to 60 DAT (Fig. 1). It increased again at slow pace at 60-100 DAT and reached a maximum value of around 150 cm at 100 DAT (Fig. 1). Growth rate with respect of plant height was smaller at 20-40 DAT. However, during this phase, growth rate was the highest in terms of tillering therefore corresponded to active tillering stage of Basmati 515.

A rapid increase in plant height observed between 40 and 60 DAT explained why tillers number declined during this growth period. Different plant spacings could not produce any significant effect on plant height of Basmati 515 during the entire crop growth period. Similar plant heights in rice transplanted in different plant spacing was also observed by Chakrabortty *et al.* (2014). In contrary, Bozorg *et al*. (2011) found tall statured plants in closer plant spacing compared to those grown at wider plant spacings. This variation may be ascribed to differences of genotypes in these studies. Plant height during growing period from 20 to 40 DAT remained almost constant which was corresponding to active tillering stage. This was probably due to fact that during this stage, plant accumulates all its photosynthates to newly producing tillers. Further, after 40 DAT a very rapid increase in plant height occurred and plants attain almost double height within growing period of 20 days in all spacings. The growth duration between 40 to 60 DAT was considered to be highly sensitive as it corresponds to panicle initiation growth phase. Nitrogen application at 50 DAT might remain beneficial in increasing plant height due to elongation of intermodal lengths. This leads us to conclusion that time of N application needs to be revisited to manage plant height in Basmati 515. Moreover, N application after 60 DAT might contribute more towards increasing grain yield by improvement in grain yield components as there is very less increase in plant height occurs by N application at this growth phase may contribute less towards plant height.

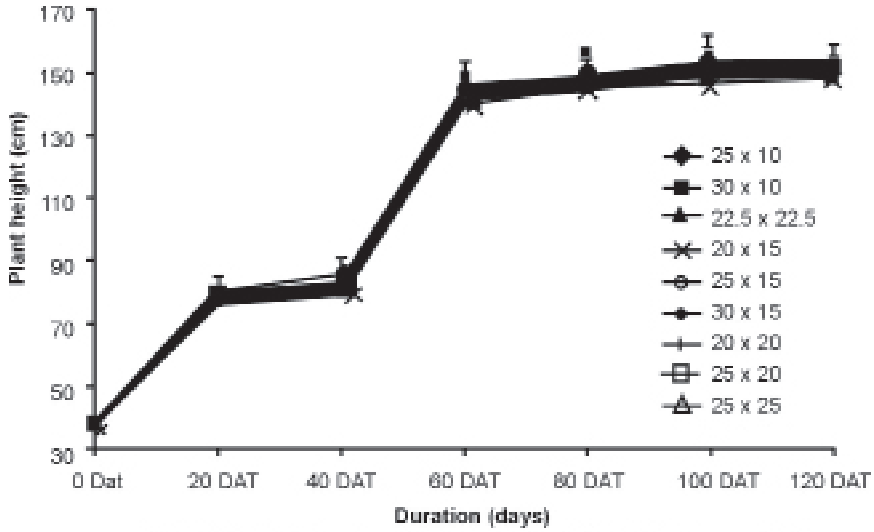

Fig. 1. Effect of plant spacing on plant height (cm) of Basmati 515

Number of tillers m^{-2}

The results regarding tillers m^{-2} of Basmati 515 are presented in Fig. 2. Number of tillers in all treatments increased up to 40 DAT except in 25×25 cm, 25×20 cm and 30×15 cm which attained maximum number at 60 DAT. It was also observed that crop attained the highest tiller production rate from sowing up to 20 DAT compared to other crop stages. The maximum tillering stage was influenced by plant spacings. Closer plant spacings reached this stage earlier (40 DAT) than wider transplanting (60 DAT). After maximum tillering stage (40 and 60 DAT), a decline in number of tillers m^{-2} was observed in all spacings to varying degree.

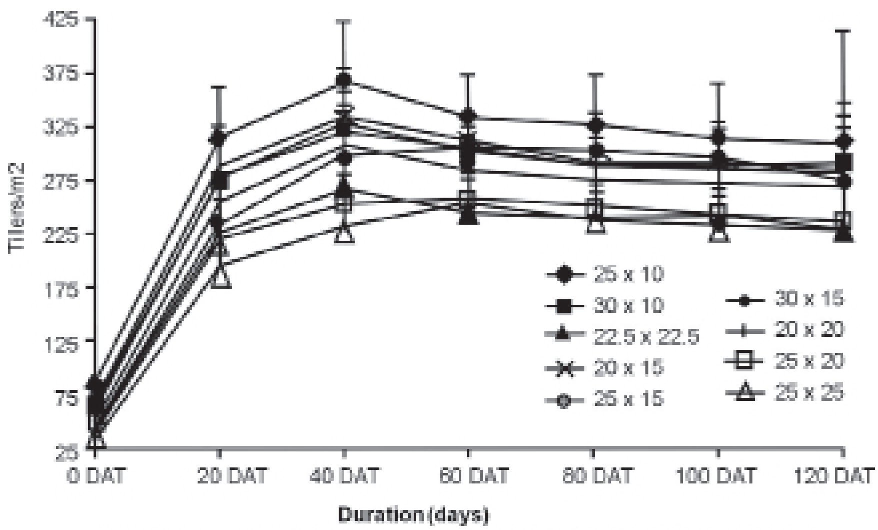

Fig.2. Effect of plant spacing on number of tillers/m2 in Basmati 515

Tillers mortality rate was higher in closer than widely spaced plants. One of the reasons of higher tillers number during 40 to 60 DAT might be the N fertilizer supply at 30 DAT and 50 DAT that decreased the tiller mortality rate. According to number of tillers m^{-2}, all plant spacings may be categorized into three groups. The narrowest plant spacing (25×10 cm) produced the maximum number of tillers (360 m^{-2}) while the lower numbers were recorded from wider plant spacings (25×25 cm, 25×20 cm and 22.5×22.5 cm). All other treatments were intermediate. All plant spacings could be categorized into two classes with respect to occurrence of maximum tillering (MT) stage. Rice planted at wider spacing (25×25 cm, 25×20 cm and 30×15 cm) reached their MT stage at 60 DAT, that was reached at 40 DAT in all other plant spacings. The difference of MT stage in various plant spacing may be attributed to competition for space, light and other growth factors which was intensive in closer than widely spaced plants. Number of tillers m^{-2} start to decline after reaching maximum tillering stage due to inter-tiller competition for limited resources but rate of decline was quite small in almost all treatments. Closer plant spacing caused higher mortality rate of tillers as compared to wider one. Plant spacing attaining maximum number of tillers at 60 DAT showed less mortality percentage (7.8-9.7%) while a higher tiller mortality percentage (9.7-16.2%) was noted with other spacings. Basmati 515 proved to be low tillering variety but showed only upto 16% tiller mortality percentage. Hussain *et al.* (2014) calculated the lower mortality rate in NERICA-4, low tillering rice variety than japonica and indica varieties. The maximum tiller survival percentage was observed with 25×20 cm (92.2%) and 25×25 cm spacings (91.5%) due to more availability of space and light. Higher tiller mortality in rice from closer planting was probably due to more inter-tiller competition for environmental resources. These results corroborate the findings of Rasool *et al*. (2013) who observed more number of effective tillers m^{-2} from rice planted at 15×15 cm spacing compared with those planted at from 15×20 cm and 20×20 cm spacing.

Yield and yield components

The results of the current study demonstrated a significant influence of plant spacing on number of panicles m^{-2}, straw yield and paddy yield of Basmati 515 (Table 1). Closer plant spacings produced more number of panicles per m^2 of Basmati 515 as compared to those produced by wider spacings that directly related to the number of tillers m^{-2}. The maximum number of panicles m^{-2} (309.3 to 275.5) were achieved in the plots having rice transplanted at 25×10 cm, 30×10 cm, 20×15 cm, 25×15 cm, 20×20 cm and 30×15 cm line to line and plant to plant spacings. The lowest (226.4) number of panicles m^{-2} was counted in plots having 22.5×22.5 cm spacing. Wider plant spacing (25×25 cm, 25×20 cm and 22.5×22.5 cm) produced lower number of panicles m^{-2} despite the bigger panicle count per hill noted from these spacings probably as a results of reduced number of hills per unit area. Moreover, the higher tiller count m^{-2} seems to be the cause of higher panicle number per m^2 in closely spaced crop. Our results are in line with earlier findings of Amin et al. (2004) that reported the higher panicle count from closer planting geometry of rice than in wider one.

Table 1. Effect of plant spacing on yield and yield components of Basmati 515.

Spacing (cm)	Panicles m^{-2}	Grains panicle^{-1}	1000 grain weight (g)	Straw yield (t ha^{-1})	Paddy yield (t ha^{-1})
25×10	309.3 a	84.93	22.67	14.8 a	3.81 a
30×10	289.9 a	90.33	22.93	14.7 ab	3.79 ab
20×15	283.3 a	85.10	22.60	14.6 ab	3.69 ab
25×15	276.4 ab	89.93	22.43	13.8 ab	3.66 ab
20×20	269.1 abc	86.97	22.87	14.5 ab	3.61 ab
30×15	275.5 ab	88.80	22.20	14.5 ab	3.46 bc
25×20	236.0 bc	86.77	23.10	13.5 ab	3.18 cd
22.5×22.5	226.4 c	87.27	23.33	12.8 b	3.11 cd
25×25	229.3 c	89.20	23.67	12.9 b	2.95 d
LSD (5%)	43.63	NS	NS	1.88	0.35

Figures sharing same letter(s) in a column do not differ significantly at 5% probability level

Plant spacing kept in the study (25×10 cm to 25×25 cm) could not produce significant influence on grain count per panicle as well as 1000-grain weight of rice. Our findings confirmed the earlier studies conducted by Patel (1900) who concluded that there was no significant influence of plant spacing on grain count per panicle and grain weight of rice. Similar response of grain weight of rice to varying plant spacing was also noted by Salahuddin *et al.* (2009). Contrarily, Baloch *et al*. (2002) reported that higher 1000-grains weight and more number of grains per panicle were produced from 25×25 cm and 22.5×22.5 cm plant spacings than 20×20 cm. These opposite results may be due to genotypic differences in both studies.

The highest straw yields (14.8 to 13.5 t ha^{-1}) of Basmati 515 were produced in the plots transplanted with rice seedlings at spacings ranging from 25×10 to 25×20 cm (Table 1). While the lowest straw yield (12.8 t ha^{-1}) was recorded with 22.5×22.5 cm spacing. Higher straw yield was obtained in closer plant spacings. Maximum straw yield from the closest plant spacing (25×10 cm) might be resulted due to more tiller count m^{-2}. The outcomes of present study are in close adherence to findings of Amin *et al*. (2004) of getting higher straw yields from its dense plant spacing (20×10 cm) of IR-6 rice compared to from wider (20×20 cm) one. Paddy yield of Basmati 515 was increased significantly with decreasing transplanting distance (Table 1). The maximum paddy yields (3.81 to 3.61 t ha^{-1}) were recorded with plots where seedlings were transplanted at 25×10 to 30×15 cm spacings. The minimum (2.95 t ha^{-1}) paddy yield was recorded with planting geometry of 25×25 cm. Higher paddy yields were recorded with closer plant spacings (25×10 cm, 30×10 cm, 20×15 cm etc.) compared to those noted with wider plant spacings (25×25 cm, 25×20 cm and 22.5×22.5 cm). The yield increments in these plant spacings were resulted due to more panicle count per m^2 as revealed by the strong positive correlation of paddy yield with panicle count per m^2 (R^2=0.9109) and sink capacity (R^2=0.8572) (Fig. 3 and 4). The previous studies also proved that paddy yields remained higher in rice crop transplanted in closely spaced plant geometries compared to those obtained in wider ones (Bozorgi *et al.,* 2011; Salahuddin *et al.,* 2009).

Economical and Marginal Analyses

Economic analysis presented in Table 2 showed the maximum variable cost ha^{-1} (Rs. 34657) from 25×10 cm plant spacing followed by 30×10 cm and 20×15 cm (Rs. 2888) and 25×15 cm (Rs. 23105). The lowest cost (Rs. 13863) was recorded from 25×25 cm plant to plant and line to line spacing. The maximum and minimum net benefits were observed from 20×20 cm (Rs. 105149) and 25×25 cm (Rs. 90614), respectively. Marginal analysis demonstrated that in an order of increasing variable costs, a viable marginal rate of return was achieved up to plant spacing of 20×20 cm (Table 3). It means that additional cost expended on increasing plant population of rice by narrowing down plant spacing up to 20×20 cm gained benefit. Therefore, a further decrease in plant spacing was irrational. The higher net benefit was obtained from 20×20 cm plant spacing. Wider (25×25 cm, 25×20 cm, 22.5×22.5 cm) and closed spacings (25×10 cm, 30×10 cm, 20×15 cm) gave lower net benefits either due to higher variable costs or lower paddy yields. Marginal analysis indicated that we can reduce plant spacing up to 20×20 cm. Further decrease in plant spacing below 20×20 cm is wastage of resources. Economic analysis proved 20×20 cm plant spacing to be the most suitable for Basmati 515. Mondal *et al.* (2013) also suggested 20×20 cm plant spacing to be most suitable for cultivating rice varieties with high yield potential.

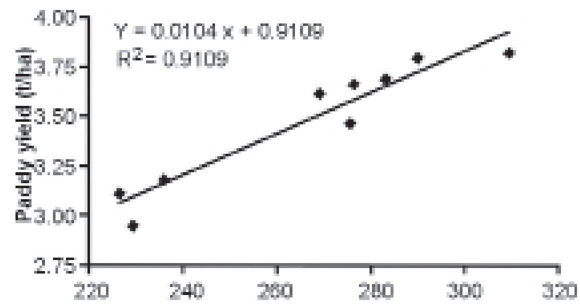

Fig. 3. Relationship between number of panicles/m^2 and paddy yield (t/ha) of Basmati 515

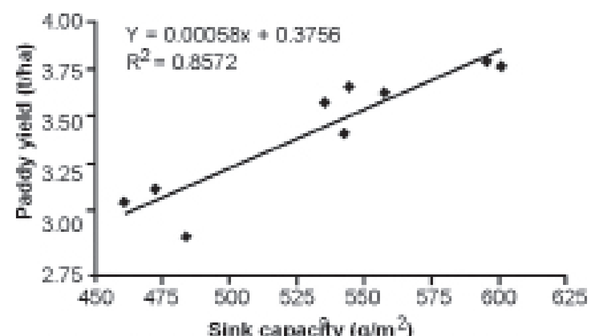

Fig. 4. Relationship between sink capacity (g/m^2) and paddy yield (t/ha) of Basmati 515

Table 2. Economic analysis of plant spacing in Basmati 515

Plant spacing (cm)	25×10	30×10	20×15	25×15	20×20	30×15	25×20	22.5×22.5	25×25
Paddy yield (t/ha)	3.81	3.79	3.69	3.66	3.61	3.46	3.18	3.11	2.95
10% less	0.38	0.38	0.37	0.37	0.36	0.35	0.32	0.31	0.29
Adjusted paddy yield	3.43	3.41	3.32	3.29	3.25	3.11	2.86	2.80	2.65
Paddy income (Rs.)	120109.5	119348.25	116098.50	115279.5	113709.75	108869.25	100196.25	98017.50	92804.25
Straw yield (t/ha)	14.85	14.71	14.68	13.84	14.56	14.54	13.57	12.89	12.97
10%less	1.49	1.47	1.47	1.38	1.46	1.45	1.36	1.29	1.30
Adjusted straw yield	13.37	13.24	13.21	12.46	13.10	13.09	12.21	11.60	11.67
Straw income (Rs.)	13368.30	13240.05	13212.90	12456.30	13101.15	13089.45	12212.25	11599.50	11673.45
Gross income (Rs.)	133477.8	132588.30	129311.40	127735.8	126810.90	121958.7	112408.5	109617.00	104477.7
Nursery raising cost	5062.50	4218.75	4218.75	3375.00	3164.06	2812.50	2531.25	2500.00	2025.00
Nursery uprooting	5001.75	4168.13	4168.13	3334.50	3126.09	2778.75	2500.88	2470.00	2000.70
Nursery transplanting	17506.13	14588.44	14588.44	11670.75	10941.33	9725.63	8753.06	8645.00	7002.45
Harvesting and threshing	7087.50	5906.25	5906.25	4725.00	4429.69	3937.50	3543.75	3500.00	2835.00
Cost that vary	34657.88	28881.56	28881.56	23105.25	21661.17	19254.38	17328.94	17115.00	13863.15
Net benefit (Rs.)	98819.92	103706.74	100429.83	104630.55	105149.72	102704.33	95079.56	92502.00	90614.55

Table 3. Marginal analysis of plant spacing in Basmati 515

Spacing (cm)	Cost that vary (Rs.)	Net benefit (Rs.)	Marginal cost (Rs.)	Marginal benefit (Rs.)	MRR (%)
25×25	13863.15	90614.55	-	-	-
22.5×22.5	17115.00	92502.00	3251.85	1887.45	58
25×20	17328.94	95079.56	213.94	2577.56	1205
30×15	19254.38	102704.33	1925.44	7624.76	396
20×20	21661.17	105149.72	2406.80	2445.39	102
25×15	23105.25	104630.55	-	-	-
20×15	28881.56	103706.74	-	-	-
30×10	28881.56	100429.83	-	-	-
25×10	34657.88	98819.92	-	-	-

CONCLUSION

The study concluded that plant spacing of 20x20 cm achieved the maximum economic yield in Basmati 515. Therefore, seedlings of Basmati 515 should be transplanted in field with planting geometry of 20×20 cm instead of 22.5×22.5 cm plant to plant and line to line spacing for achieving maximum benefits.

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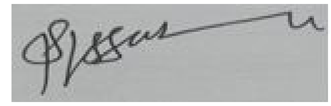
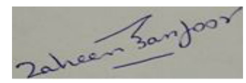
1.	Shahbaz Hussain	Planned and executed the research, collected and analyzed the data, prepared write-up	
2.	Muhammad Ramzan	Planned and supervised the research	
3.	Muhammad Ehsan Safdar	Prepared write-up	
4.	Zaheen Manzoor	Edited the article	
5.	Tahir Husssain	Statistically analyzed the data