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Testing and evaluation of planting methods on wheat grain yield and yield contributing parameters in irrigated agro-ecosystem of western Uttar Pradesh, India

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A field experiment was carried out during three consecutive years 2008 to 2009 and 2010 to 2011 at two locations; one at University research centre and another at farmers' fields in Meerut and Muzaffarnagar district of western Uttar Pradesh, India. The objective of the study was to compare the conventional planting methods (22.5 cm) and broadcasting method of wheat sowing with drill planting method [15.0, 17.5, 20.0 cm and paired row (15:25 cm)] for grain yield and its parameters. The experiment comprised of six (15, 17.5, 20, 22.5 and 15:25 cm paired spaced rows and broad casting) treatments arranged in randomized complete block design with three replications in a net plot size of 13 × 8 m. The results over the years of the study revealed that, the germination were statistically at par in drill sowing at 17.5 cm apart rows and broadcasting. Better plant height was noted in drill planting with 17.5, 20 cm rows and 15:25 cm paired rows. However, number of spikelets spike^{-1} and number of grains spike^{-1} were statistically similar in drilling at 17.5, 20, and 15:25 cm paired apart rows. Similarly, 1000 grain weight was recorded in drill sowing at 20 cm and 15:25 cm paired rows. The maximum grain yield was obtained through 15:25 cm paired rows drill planting method and it was statistically at par with drill planting method where row spacing was 20 cm. Whereas, drill-planting techniques with row spacing 15 cm was inferior to broadcast method. It may be concluded that, 15:25 cm paired rows and 20 cm drill planting method is suitable for wheat sowing in sandy loam soils of irrigated areas of western Uttar Pradesh.

Key words: *Triticum aestivum* L., planting methods, water productivity.

INTRODUCTION

Wheat (*Triticum spp.*) is one of the most important cereal crops in the world. It is grown across a wide range of environments around the world and has the highest adaptation among all the crop species. Worldwide more land is devoted to the production of wheat than any other crop. It is the main staple food of nearly 35% of the world population than any other food source. It is the only crop so far reported to produce more than 500 million tonnes of yield in a single year. Wheat is a rich source of protein, minerals, and vitamins amongst all the cereals. It

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contributes about 60% of daily protein requirement and more calories to world human diet than any other food crops (Mattean et al., 1970). In India wheat is the second most important food crop next to rice and it contributes nearly 35% to the national food basket. Among winter crops, it contributes about 49% of the food grains. During the crop year 2003 to 2004 the area under wheat was 26.58 000 000 ha with a production of 72.10 million tonnes, average productivity being 2710 kg/ha (Anon, 2005).

The assessment on the scientific, technical, and institutional issues associated with wheat crop is urgently needed. For the past 40 years, the growth in the productivity of wheat crop was the result of technological innovations in the form of green revolution. With the result, supply exceeded demand and real prices of food such as cereals went down. However, the yield growth rate of many crops especially cereals have started declining. Reasons for declining in the productivity growth rate are multiple (Duxbury et al., 2000).

Sustainability and profitability of wheat crop system in Indian agriculture is the lifeline and future of Indian economy with more than 60% people living in rural areas. The challenges are enormous ranging from conservation of natural resources to investment in new technologies based on biotechnology. Increasing food production of the country in the next 20 years to much population growth is a big challenge in India. It is more difficult because, land area devoted to agriculture will stagnate or decline and better quality of land and water resources will be divided to the other sector of national economy. In order to grow more food from marginal and good quality lands, the quality of natural resources like seed, water, varieties, and fuel must be improved and sustained.

On the other hand, establishment of optimum plant density, culture methods are important factors for securing good yield of crop, particularly in wheat. Variety plays an important role in producing high yield of wheat because different varieties responded differently for the genotypic characters, input requirement, growth process and the prevailing environment during growing season (Gupta et al., 2000). Narrow row culture in wheat is supposed to be one of the most effective techniques of pre-serving resource base and has manifold advantages. It is the new concept in western Uttar Pradesh irrigated areas. This technique in wheat cultivation helps in saving moisture, reduces water requirement, increases yield, reduces lodging, increase sourse-sink relationship, allows better surface, basal and top dress, fertilizer placement and promotes rain water conservation.

The green revolution is one of the most striking success stories of post-independence India. The success was reflected through more efficient dry matter partitioning to reproduction and therefore, higher harvesting index with significant gain in the yield potential. It is the combination of green revolution varieties and their responses to external inputs, which produced meaningful advances in agricultural productivity. More than 90% farmers have adopted semi-dwarf wheat by 1997 (Pingali, 1999). It is not easy to escape a general relationship between grain productivity and fertilizer nitrogen especially after the evolution of semi-dwarf varieties. It is estimated that, irrigated lands have expanded to reach 268 m ha with 80% in developing countries and much in Asia. This expansion is now slowing down (FAO, 1998). In addition to nitrogen fertilizers and expansion of irrigation, there has been a consistent increase in the use of external inputs including pesticides.

Thanks to green revolution, the higher food availability without using the extra land represents a success story in agriculture. These were not varieties alone which transformed the food production scenario, but the response of these varieties to external inputs brought about a major change in the food production. The gross consumption of fertilizers increased 25 fold in developing countries to reach 91 mt in 2002, but only increased 2 fold in developed countries. The use and rates in the developing countries surpassed that in the developed countries in the early 1990s (Cassman et al., 2003). The green revolution has slowed down sharply, as has yield growth, since the 1980s. The slow down or even reversal has been due to water table lowering because of ever deeper tube wells, micronutrient depletion, monoculture, reducing biodiversity and buildup of insect, diseases and weeds, development of resistance against pesticides and high concentration of pesticides or fertilizer-derived nitrates and nitrites in water courses.

The amelioration of above factors adds to the cost of cultivation and, therefore, a decline in the total factor productivity. With the rise in input cost, the net profit of farmers has fallen even if the productivity is increasing slightly. Each farmer, therefore, needs to maximize earnings through alternate technologies. Seen from profitability point of view, it will be important to maintain natural resources. Resources Conservation that is, narrow row spacing, therefore, have become a critical component to growth in agriculture. Carver (2005) investigated the impact of different crop establishment methods, that is, conventional drilling, precision drilling and broadcasting in winter wheat. Broad-casting method produced the most effective spatial arrangements. However, there was no consistent relationship between any of the spatial arrangement and subsequent yield performance. Singh et al. (2005) concluded from a field experiment in Uttar Pradesh, India, that in wheat, strip drilling resulted in higher growth and grain yield (5.67 t ha^{-1}), followed by zero tillage drilling, conventional sowing and bed planting. The broadcast sowing generally gave lower yield than sowing in rows Krezel and Sobkowicz (1996). However, Ahuja et al. (1996) recorded 5.08 t ha^{-1} grain yield with broad-casting while 4.75 t ha^{-1} with sowing in 23 cm apart rows, where as Raj et al. (1992), Abbas et al. (2009) found that, row spacing (15, 22.5 or

30 cm) had no effect on grain yield in 1986 to 1987 but the yields were lower in the wider row spacing (30 cm) in 1985 1986.Parihar and Singh (1995) revealed that, cross sowing increased grain yield by 4.3% compared with the normal method of sowing (line sowing). Keeping in view of irrigated environments and number of plants per acre, the study was conducted to determine the role of planting methods on wheat grain yield and yield contributing parameters in irrigated areas.

Most of the prototypes developed by the manufacturers do not possess appropriate beam size. As a result, the 22.5 cm apart row planting in wheat cannot be adopted by the farmers. They are adopting only 20 cm apart row planting. New prototypes which are available for planting consist of 13 and 18 tines also. For experimental purposes these prototypes have been used for achieving 22.5 cm row planting. Gupta and Gill (2004) investigated that, among different crop establishment methods, that is, conventional drilling, paired row planting, controlled traffic and zero till planting in winter wheat. Paired row planting resulted in 8 to 10% higher yield as compared to conventional drilling. Sharma et al. (2008) revealed that, conservation tillage practice is attractive source to farmers because the potential of reduction of production costs compared to conventional method of sowing. Botta et al. (2006), Kahloon et al. (2012) reported that, maximum increase in fuel consumption reduced the economic benefit of the farmers, so that tillage equipments are used in sowing of wheat. In case of zero tillage technique there is no need of soil preparation, it operates on fellow land at watter condition.

This paper presents results of planting methods on-farm experiment and observations from wheat grain yield and yield contributing parameters in irrigated agro-ecosystem of western Uttar Prades, India.

MATERIALS AND METHODS

Two set of experiments on different crop establishment techniques involving planting methods were conducted under researcher managed trials at the research farm (29°01' N, 77°45' E, and 237 m above mean sea level) of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (Uttar Pradesh), India and farmer managed trials in Meerur and Muzaffarnagar district of Uttar Pradesh in western Gangetic Plain during 2008 to 2009 to 2010 to 2011. The water table depth of the experimental sites is 23 m with very good quality of water. The climate of the area is semiarid, with an average annual rainfall of 765 mm (75 to 80% of which is received during July to September), minimum temperature of below 4°C in January, maximum temperature of 41 to 45°C in May to June, and relative humidity of 67 to 83% throughout the year. The experimental soil (0 to 15 cm) was sandy loam in texture, with a bulk density of 1.48 Mg m^{-3}, weighted mean diameter of soil aggregates 0.74 mm, pH = 7.9, total C = 8.3 g kg^{-1}, total N = 0.83 g kg^{-1}, Olsen P = 28 mg kg^{-1}, and K = 128 mg kg^{-1}.

The experiment was initiated during Rabi 2008-09 at Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.) research farm involving six planting techniques. A randomized complete block design (RCBD) was used in the study.

A combination of six crop establishment techniques [T_1 = Broadcasting (Control), T_2 = Planting at 15 cm apart rows. T_3 = Planting at 17.5 cm apart rows, T_4 = Planting at 20 cm apart rows, T_5 = Planting at 22.5 cm apart rows, T_6 = Planting at 15:25 cm paired rows].The farmers' participatory trials was also initiated during 2008 to 09 on crop establishment techniques at fifteen locations (one farmer at each location) in Meerut and Muzaffarnagar district of western Uttar Pradesh, India for three years on wheat crop. These trials were researcher-designed and farmer-managed, with a single replicate, repeated over many farmers. In general the soils of the farmers' fields were sandy loams with medium fertility. The particle size distribution of the 0 to 20 cm soil layer is 69.2% sand, 16.1% silt and 14.9% clay. Six crop establishment techniques [T_1 = Broadcasting (Control), T_2 = Planting at 15 cm apart rows. T_3 = Planting at 17.5 cm apart rows, T_4 = Planting at 20 cm apart rows, T_5 = Planting at 22.5 cm apart rows. T_6 Planting at 15:25 cm paired rows].

Seeding and seed rate

'PBW-343' wheat variety was seeded on 20th Nov. 2008, 2009 and 2010, respectively. A seed rate of 100 kg ha^{-1} was used in all the treatments. The multicrop planter with enclined plate seed metering device machine was used for line sowing and was calibrated every time before seeding to adjust the seeding rate along with all other intercultural operations were conducted to ensure a healthy crop stand in the field.

Fertilizer application

Recommended dose of NPK was applied according to treatments as urea, triple supper phosphate, and sulphate of potash, respectively. One third of urea and all other fertilizers were broadcasted and incorporated into the soil at the time of final land preparation. The remaining urea was top dressed in two equal splits. The first split was applied at crown root initiation stage (21 days after sowing) and 2nd at maximum tillering stage followed by irrigation.

Weed management

The crop was maintained with weed free using following practices. Grassy weeds were controlled by spraying of sulfosulfuron at 35 g a.i. ha^{-1} at 30-45 DAS, and broad leaf weeds using 2, 4-D at 500 g a.i. ha^{-1} at 35 DAS.

Water application and measurements

Irrigation water was applied using polyvinyl chloride pipes of 15 cm diameter and the amount of water applied to each plot was measured using a water meter (Dasmesh Co., India).The quantity of water applied and the depth of irrigation were computed using the following equations:

$$\text{Quantity of water applied (L)} = F \times t \quad (1)$$

$$\text{Depth of water applied (mm)} = L / A / 1000 \quad (2)$$

where F is flow rate (l s^{-1}), t is time (s) taken during each irrigation and A is area of the plot (m^2). Rainfall data were recorded using a rain gauge installed within the meteorological station. The total amount of water (input water) applied was computed as the sum of water received through irrigation and rainfall (I+R). Water productivity (WP_I+_R) (kg grains m^{-3} of water) was computed as

Table 1. Response of planting methods on germination, number of tillers and plant height in wheat.

Planting method	Germination per m²				Number of tillers per m²				Plant height in m²			
	2008-2009	2009-2010	2010-2011	Mean	2008-2009	2009-2010	2010-2011	Mean	2008-2009	2009-2010	2010-2011	Mean
T_1	230	213	192	212	247	251	264	254	99.3	99.8	93.8	97.6
T_2	273	242	217	244	238	244	281	254	100.6	101.9	95.5	99.3
T_3	262	223	207	231	254	258	296	269	102.7	102.8	97.9	101.1
T_4	252	210	200	221	267	274	309	283	103.9	104.7	98.2	102.3
T_5	213	198	179	198	229	236	257	241	98.4	100.3	93.4	97.4
T_6	249	217	206	224	261	277	306	281	104.5	105.1	98.8	102.8
C D at 5%	34.41	14.72	17.30	13.73	N S	31.71	46.3	17.6	1.64	1.97	1.14	1.87

follows (Humphreys et al., 2006):

WP_{I+R} = grain yield (kg ha^{-1}) / [irrigation water applied (m^3) + rainfall received by the crop (m^3)]ha^{-1}.

Data on yield and yield attributing characters were recorded at harvest. Recorded data were analyzed following the ANOVA technique and mean differences were adjudged by Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984) with the help of computer package M-STAT.

RESULTS AND DISCUSSION

Germination (m^2)

It is evident from Table 1 that, during the first year of the experiment, planting at 15, 17.5, and 20.5 cm and 15:25 cm paired row method produced similar and higher germination m^2. However, statistically low germination was produced when crop was sown in T_6 22.5 cm spaced rows. During 2009 to 2010 and 2010 to 2011, T_2 that is, 15 cm planting method or spacing influenced germination significantly. Treatments T_3, T_4, and T_6 were at par during the years. The mean of three years results showed that, statistically similar germination was recorded in (T_2 andT_3) 15, 17.5 cm apart planting method, however, T_3 17.5 cm, T_4 20 cm was also at par with planting in T_6 15:25 cm paired rows. Wheat planting at T_5 22.5 cm apart rows produced minimum germination per unit area. Hence, it can be concluded from the results that, in western U.P. area, germination were similar for (T_3 and T_4), 17.5 and 20 cm apart rows the planting methods. It might be attributed to the sandy loam soil and optimum soil moisture conditions, which played major role in germination of wheat crop.

Tillers (m^2)

Neither planting methods that is neither broadcast nor drill planting nor row spacing of (15, 17.5, 20, 22.5 and 15:25 cm) influenced tillering in wheat during first year of the experiment. Moreover, the tillers during 2009 to 2010 and 2010 to 2011 the years individually or average of the years showed poor tillering in T_6 22.5 cm apart rows and T_1 broad-casting method treatments under study. Less tillering can be attributed to the low fertility status and less water holding capacity of sandy loan soils of the area Table 1.

Plant height (cm)

The data presented in Table 1 depicted that, during the year 2008 t0 2009, the maximum plant height of 104.5 cm was produced when wheat was sown in T_6 15:25 cm paired spaced rows, however, broadcast (99.3 cm), T_2,15 cm (100.6) and T_5 22.5 cm spaced rows (98.4 cm) were also statistically at par. The minimum plant height of 98.4 cm was produced at T_5 22.5 cm row spacing. During next year that is, 2009 to 2010, row spacing of T_6 15:25 cm paired row, T_4 20 cm and T_3 17.5 cm produced significantly similar but taller plants (105.1, 104.7 and 102.8 cm), while row spacing of T_5 22.5 cm was also statistically at par with broadcasting method (99.8 cm). Almost same trend was observed in 2010 to 2011.The average of three years data expressed the similar trend as in the year (2008 to 2009). The less difference of plant height in the planting methods can be described to the appropriate plant population and inherent varietal character of wheat variety PBW-343.

Number of spikelet spike^{-1}

It is evident from Table 2 that, maximum number

Table 2. Effect of planting methods on yield attributes of wheat.

Planting method	Number of spikelets spike^{-1}				Number of grains spike^{-1}				1000 grain weight in (g)			
	2008-2009	2009-2010	2010-2011	Mean	2008-2009	2009-2010	2010-2011	Mean	2008-2009	2009-2010	2010-2011	Mean
T_1	13.30	11.70	12.20	12.40	51.0	52.0	46.7	49.9	36.3	35.7	37.8	36.6
T_2	12.10	11.60	11.90	11.9	42.7	43.8	44.2	43.6	36.7	36.1	38.3	37.0
T_3	14.40	13.20	13.60	13.7	49.5	49.0	48.5	49.0	42.3	41.6	41.3	41.7
T_4	15.37	14.17	14.05	14.5	53.0	55.5	52.6	53.7	42.6	42.4	42.8	42.6
T_5	11.90	11.25	11.70	11.6	45.3	44.7	45.8	45.3	39.5	40.5	40.7	40.2
T_6	16.25	14.85	15.20	15.4	54.0	56.6	53.8	54.8	42.9	42.9	42.7	42.8
C D at 5%	1.07	1.37	0.81	1.21	3.94	6.57	4.34	4.73	0.91	1.28	1.57	1.34

of spikelets spike^{-1} were recorded in T_6 15:25 cm paired rows planting method of seed placement during the year 2009 to 2010 (14.85) as well as average over three years (15.4). In 2008 to 2009, planting at T_6 15:25 cm paired rows produced the maximum number of spikelets per spike (16.25), although it was statistically at par and closely followed by the T_4 20 cm apart rows planting method (15.37). More number of spikelets per spike in T_4 20 cm and T_6 15:25 cm row planting can be referred to the ideal plant population in the both treatments which resulted in less crop plant competition.

Number of grains spike^{-1}

It is clear from the data shown in Table 2 that, the number of grains spike^{-1} were produced in T_6 15:25 cm paired rows planting method during 2008 to 2009, 2009 to 2010, 2010 to 2011 and pooled of the years (54.0, 56.6, 53.8, and 54.8 respectively). However, drill planting at T_4 20 cm produced statistically similar number of grains spike^{-1} during individual years (53.0, 55.5, and 52.6) and average over the years (53.7). The lowest numbers (42.7, 43.8, 44.2, and 43.6, respectively) were produced when planting was done in T_2 15 cm spaced rows during the individual year and average of the years as well ($P < 0.05$).

1000 grain weight (g)

It is clear from the data presented in Table 2, that during the year 2008 to 2009, and 2009 to 2010, the maximum 1000 grain weight of 42.8 and 43.1 g was produced by T_6 15:25 cm paired row spacing method. The row spacing of T_3 17.5 cm and T_4 20 cm also remained statistically at par with the above-mentioned treatments with 1000-grain weight. Planting at a distance of T_2 15 cm and T_1 broad-casting produced the lowest weight of 36.7, 36.1 and 36.3, 35.7 g. The average of three years results showed similar trend as in 2008 to 2009.

Grain yield (kg ha^{-1})

The data presented in Table 3 for grain yield revealed that, during 2008 to 2009, the maximum grain yield of 4491 kg ha^{-1} was produced when wheat was sown at T_6 15:25 cm paired rows. The maximum grain yield producing treatment, however, was at par with T_3 17.5 cm and T_4 20 cm apart rows planting method of sowing with a grain yield of 4316 and 4463 kg ha^{-1}. Planting at T_2 15 cm apart rows and T_1 broad-casting method produced grain yield of 3970 and 4083 kg ha^{-1}, which were statistically lower than the above-mentioned treatments, although at par with one another. During next year, that is, 2009 to 2010 and 2010 to 2011, T_6 15:25 cm paired rows planting method produced the maximum grain yield of 4635, 4760 kg ha^{-1} than all the method and treatments, which produced 4567, 4470, 4369, 4292, 3840, and 4714, 4682, 4432, 4367, 3725 kg ha^{-1} of grain yield, respectively. The trend of average data for three years was similar to that produced during the year 2010 to 2011 with T_6 15:25 cm paired rows planting method at the top (4629 Kg ha^{-1}). The T_6 15:25 cm paired row spacing obtained 7 to 10% higher yield as compared to conventional method that is, T_1 broadcasting method of wheat planting. The maximum grain yield in T_6 15:25 cm paired row spacing method of sowing can be described to higher number of spikelet's spike^{-1}, number of

Table 3. Grain and straw yield (Kg/ha) of wheat as influenced by methods of planting in wheat.

Planting method	Grain yield (Kg/ha^{-1})				Straw yield (Kg/ha^{-1})			
	2008-2009	2009-2010	2010-2011	Mean	2008-2009	2009-2010	2010-2011	Mean
T_1	4083	4292	4367	4247	4140	4352	4428	4307
T_2	3970	3840	3725	3845	4026	3892	3775	3920
T_3	4316	4470	4682	4489	4376	4533	4748	4552
T_4	4463	4567	4714	4581	4530	4636	4785	4650
T_5	4213	4369	4432	4338	4272	4430	4494	4399
T_6	4491	4635	4760	4629	4558	4705	4831	4698
C D at 5%	198.3	167.4	141.7	163.6	197.4	176.3	141.7	159.3

Table 4. Water application and water productivity of wheat with various methods of planting .

Planting method	Irrigation water applied (mm ha^{-1})			Water productivity (Kg grain m^{-3})		
	2008-2009	2009-2010	2010-2011	2008-2009	2009-2010	2010-2011
T_1 Broadcasting (Control),	445	432	435	0.917	0.993	1.005
T_2 Planting at 15 cm apart rows	436	420	430	0.911	0.914	0.867
T_3 Planting at 17.5 cm apart rows	413	397	395	1.046	1.126	1.185
T_4 Planting at 20 cm apart rows	405	385	391	1.101	1.187	1.205
T_5 Planting at 22.5 cm apart rows	425	410	405	0.991	1.066	1.102
T_6 Planting at 15:25 cm paired rows	437	425	412	1.027	1.092	1.155

grains spike^{-1} and 1000 grain weight, which was favored because of better growing condition in row planting method. Similar findings were also reported by Carver (2005), Bruns (2011), Steckel and Gwathmey (2009), Wrather et al. (2008), Willcutt et al. (2006) and Raj et al. (1992). While the findings reported by Parihar and Singh (1995) are in contradictory to the present findings. It might be due to varying environmental and soil conditions.

Straw yield (kg ha^{-1})

Straw yield was significantly influenced by planting method. The highest straw yield (4698 kg ha^{-1}) was obtained from T_6 15:25 cm paired rows planting method and the lowest straw yield (3920 kg ha^{-1}) was obtained from T_2 15 cm row spaced planting method. These results are in the agreement with that of Rahman et al. (2010).

Input water use and water productivity

The input water use includes both irrigation water applied and the rain water that fell during the wheat season (81 mm), but not the pre-cultivation/sowing/planting irrigations. The total input water in wheat varied with planting method (Table 4) due to differences in irrigation amount. The T_1 broad-casting method consumed about 9% more water (437 mm) than T_4 20 cm apart rows planting method (394 mm) with conventional tillage, and 5% more water than with T_5 conventional planting distance (22.5 cm) method (413 mm). The higher irrigation water use in wheat with T_1 broadcasting method was due more ploughing and undulated fields. However, input water productivity of wheat on T_4 20 cm apart rows planting method was significantly higher than in all other treatments. There was also a consistent trend for higher wheat input water productivity with rows planting method as compared to T_1 broad-casting method.

Conclusions

Grain yield depends on production of photosynthates and their distribution among various plant parts. The synthesis, accumulation, and translocation of photosynthates depend upon efficient photosynthetic structure as well as the extent of translocation into sink (grains) and also on plant growth and development during early stages of crop growth. The production and translocation of synthesized photosynthates are directly or indirectly depend on agronomic practices that are followed for the culture of crop. Cropping geometry coupled with selection of variety play significant role in the performance of crop. The row spacing of 20 cm and 15:25 cm paired rows made grain yield of wheat to increase progressively. The effect on straw yield was similar. Wider row spacing intercepted significantly more light than the normal spacing. This increased productive tillers significantly, and grains per ear and grain weight slightly. This observation confirms the results of our experiment. This also supports the direct relationship between grain yield and solar radiation absorbed because in the wider spacing, light falling on the ground was better utilized for longer period.

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