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Yield, efficiency indices and economics of wheat (*Triticum aestivum* L.) varieties as influenced by variable row spacings

S.R. GHAFARI[1*], M.Q. MANGAL[1], M.N. JALALI[1], J. ALI[1] AND A. DASS[2]

[1]*Department of Agronomy, Agriculture Faculty of Ghazni University, Ghazni, Afghanistan*

[2]*Division of Agronomy, Indian Agricultural Research Institute, New Delhi-110012, India*

**sayedrahim23@gmail.com*

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ABSTRACT

A study was conducted during 2015 winter at Tarnak Research Farm of Afghanistan National Agriculture Science and Technology University, Kandahar to find out effect of row spacing on different varieties of wheat cultivation. The treatments comprised of three wheat varieties (PBW 154, Darulaman 07 and Herat 99) and three row spacing (20, 25 and 30 cm). The experiment was laid out in a randomised block design with three replications. Result indicated that among three wheat varieties, Herat 99 produced significantly higher grain yield (3.71 t ha^{-1}), straw yield (6.17 t ha^{-1}), production use efficiency (28.8 kg ha^{-1} per day) and irrigation water-use efficiency (10.6 kg ha^{-1} mm^{-1}) than Darulaman 07. But, harvest index was not influenced by varieties significantly. Biological yield (9.88 t ha^{-1}), output energy (131,709 MJ ha^{-1}) and energy use efficiency (7.5) of Herat 99 were significantly greater than other varieties. Herat 99 variety produced significantly higher gross returns (173,078 Afn. ha^{-1}) and net returns (119,681 Afn. ha^{-1}) than other varieties. The B:C ratio (2.2) was in Herat 99 variety significantly higher than Darulaman 07. Planting at 20 cm row spacing resulted in significantly higher grain yield (3.71 t ha^{-1}), straw yield (6.17 t ha^{-1}), biological yield (9.71 t ha^{-1}), production efficiency (28.8 kg ha^{-1} day^{-1}), irrigation water-use efficiency (10.6 kg ha^{-1} mm^{-1}), output energy (129,803 MJ ha^{-1}), energy use efficiency (7.4), net return (117,731 Afn. ha^{-1}) and B:C ratio (2.2) as compared to 30 cm row spacing. The gross return (171,378 Afn. ha^{-1}) were significantly higher with 20 cm row spacing than other row spacing.

Key words: Economics, efficiency indices, row spacing, wheat varieties, yield

INTRODUCTION

Wheat (*Triticum aestivum* L.) belongs to the family *Poaceae* (*Gramineae*), which includes major cereal crops, such as sorghum, maize, wheat, rice, millet and barley (Briggle and Reitz, 1963). Wheat provides 70–90% of all calories and 66–90% of the protein consumed in developing countries. Globally, wheat is the most important staple food for 40% of the population (Goyal et al., 2010; Peng et al., 2011). Wheat can be grown on both irrigated and rainfed lands with rainfall between 300 and 900 mm. Wheat is unrivalled in its range of cultivation, from 67^{o} N in Scandinavia and Russia to 45^{o} S in Argentina, including elevated regions in the tropics and sub-tropics (Feldman, 1995). Therefore, wheat is grown all over the world, with different suitable varieties according to various climates. In Afghanistan, wheat is the most important food crop and commonly the flour, is generally used for baking bread. It supplies more than half of the caloric intake of the population (Chabot and Dorosh, 2007). In our country the wheat production in 2014-15 was 5.4 MT.

Total wheat production was increased by 3.9% over to 2013–14 production level. This increase in production was the result of increase in area under cultivation (MAIL, 2014–15). The productivity of wheat in Afghanistan is very low due to lack of appropriate wheat crop production technology. A number of genetic and external factors govern the yield of wheat crop. An optimum level of single factor may not cause any appreciable increase in the yield, but a combination of yield attributes contributes to the ultimate yield of wheat. It is well recognized that by keeping proper row spacing and inputs like varieties, fertilizers and seed rate, etc. effectively increase yield of crops. Inter-row spacing is equally important in wheat for even distribution of plants in the field and for better utilization of available soil and natural resources (Mali and Choudhury, 2011). This ultimately leads to higher grain and biomass yield. Proper row spacing is important for maximizing light interception, penetration, light distribution in crop canopy and average light utilization efficiency of the leaves in the canopy and, thus, enhance yield of a crop (Hussain et al., 2003).

Row spacing requirements of wheat depend on architecture and growth pattern of the varieties. For higher yield, higher proportion of incident radiation at the soil surface must be intercepted by crop canopy (Eberbach and Pala, 2005). In case of wider row spacing, solar radiation that falls between crop rows remain unutilized otherwise plants become crowded and suffer from mutual shading if the row distance is too narrow. Moreover, yield may be reduced in narrow spacing due to increased competition of plants for nutrient and moisture (Das and Yaduraju, 2011). An uniform distribution and proper orientation of plants over a cropped area are needed for greater light interception throughout the crop profile and maximum photosynthetic efficiency by all the leaves of a plant (Evers et al., 2009). The other essential factor is wheat genotypes those are generally selected for higher yields and greater tolerance to adverse conditions and early maturity (Kumar et al., 2013). However, success of any crop production depends on the use of appropriate and selectivity of location-specific genotype or variety of high yield potential, and additionally improved cultural practices. Row spacing and optimum variety are of prime importance (Eissa et al., 1995), but all the varieties do not perform well in the same plant spacing. Optimum plant densities vary greatly between areas, climatic conditions, soil and varieties (Darwinkel et al., 1977).

Wheat is mostly planted by broadcasting method in Afghanistan, though research scientists use line sowing and advise the same to the wheat farmers. Now-a-days due to infestation of weeds, it has become important to sow the crops in lines with suitable row spacing, which besides facilitating inter-culture and convenient herbicide application for effective and efficient weed control. This reduces the seed rate per hectare without any adverse effect on the final grain yield.

There have been controversial reports in the literature regarding the role of row spacing in wheat production. Sharma and Thakur (1990) reported that grain yield was non-significantly affected by sowing wheat either at 22 or 30 cm row spacing. Raj et al. (1992) reported that row spacing (15, 22.5 or 30 cm) had no effect on grain yield, but the yields were lower in the wider row spacing (30 cm). Singh and Srivastava (1991) reported that tiller numbers, grains per spike and 1000-grain weight increased with increasing row spacing. Bakht et al. (2007) reported that maximum grain yield was obtained when wheat was sown at row spacing of 30 cm. In India, recommended row spacing for most of the wheat cultivars is 22.5 cm. In Nepal, a hilly country, Pandey et al. (2013) did not find significant yield differences in studied row spacings of 15, 20 and 25 cm. These findings indicate that response of wheat to planting spacing is location and variety specific, and this needs systematic evaluation across locations, environments and cultivars.

As in Afghanistan, not enough research work has been done towards recommending most appropriate row spacing, it is necessary to conduct an experiment in order to make farmers and researchers to take a decision for row spacing of wheat. Hence, the present study was aimed to determine the influence of row spacing on yield, efficiency and economics of wheat varieties in semi-arid region of Kandahar.

MATERIALS AND METHODS

Experiment site

The experiment was conducted at Tarnak Research Farm of Afghanistan National Agricultural Science and Technology University, Kandahar, Afghanistan, during winter season of December 2014 to May 2015. Geographically, the experimental field is located at longitude 65° 52' 1" East and latitude 31° 26' 58" North at an elevation of 986 m above the mean sea level.

Climate and soil

Kandahar province is located in the southern region of Afghanistan. The climate of this place is tropical to sub-tropical of slightly semi-arid in nature.

According to agro-climatic conditions of Kandahar state, the seasonal rainfall of about 190.6 mm is received mostly in winter season. During experimentation, the crops received a total rainfall of 49.8 mm from December 2014 to May 2015. Therefore, in addition to the rainfall, irrigation was also provided for the proper growth and development of the crop. The maximum temperature varied between 12^{o} C and 32^{o} C while minimum temperature ranged between 0^{o} C and 14.9^{o} C during the cropping period of wheat.The soil of the experimental site was sandy clay loam in texture, slightly alkaline in reaction having pH of 8.30, with a cation-exchange capacity of 80.58 m eq 100 g^{-1} and electrical conductivity of 0.210 d Sm^{-1}. The initial N (0.06 %) content of soil was low having P content of 1.23 mg kg^{-1} and K content of 1089 mg kg^{-1}.

Experimental design and treatments

The experiment design was a factorial arranged in a randomized complete block design with three replications. The two factors included of three wheat varieties (PBW-154, Darulaman-07 and Herat- 99) and different row spacing (20 cm, 25 cm and 30 cm) for each wheat variety, each replication consisting of nine treatments and in total there were 27 treatments.

Data collection

To record grain yield the weight of threshed clean grains of each experimental unit was recorded. Data for total above ground dry matter yield or biological yield was recorded by weighing bundles from each plot. Harvest index was calculated by dividing grain yield over biological yield and then multiplied with 100. For computing of benefit: cost ratio, the net return was divided with the cost of cultivation. The value so obtained was considered as cost benefit ratio.

$$\text{BCR} = \frac{\text{Net return}}{\text{Total cost of production}}$$

Production efficiency was calculated by taking the grain yield of crop to the number of days taken to achieve physiological maturity.

$$\text{Production efficincy (PE)} = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Number of days taken to maturity}}$$

The irrigation water-use efficiency was computed by taking grain yield of wheat to the amount of irrigation water applied during the entire crop season. IWUE is computed using following equation:

$$IWUE\ (ha\ mm^{-1}) = \frac{Total\ grain\ yield\ (kg\ per\ ha)}{Irrigation\ applied\ (mm)}$$

The energy values for inputs (e.g. machinery, seeds, fertilizer, water, and labour requirements) and outputs (e.g. grain and stover) were estimated using energy equivalents Behera et al. (2015) and Shahan et al. (2008) are given in the (Table 1). The energy use efficiency was calculated by equation follow: Shahan et al. (2008).

$$Energy\ use\ efficiency = \frac{Energy\ output\ (MJ\ per\ ha)}{Energy\ input\ (MJ\ per\ ha)}$$

Table 1. Energy equivalents of inputs and outputs in agricultural production for the wheat varieties under varying row spacing under Kandahar situation

Particulars	Unit	Energy equivalent (MJ per unit)
A. Inputs		
1. Human labor (man)	hr	1.96
2. Machinery (tractor)	hr	62.7
3. Diesel fuel	kg	56.31
4. Chemical fertilizers		
(a) Nitrogen (N)	kg	66.1
(b) Phosphate (P_2O_5)	kg	12.4
(c) Potassium (K_2O)	kg	11.2
(d) Zinc (Zn)	kg	8.4
7. Water for irrigation	m^3	1.02
8. Seed (maize)	kg	14.7
B. Outputs		
1. Grain wheat	kg	14.7
2. Stover	kg	12.5

Statistical analysis of data

The collected data was analysed statistically by using Fisher's analysis of variance techniques and differences among treatment means were compared using least significant difference test at 5% probability level (Steel et al., 1997).

RESULTS AND DISCUSSION

Influence on yield

Effect of varieties

The result of this study showed that different varieties significantly differed in their grain yield. Variety Herat 99 showed higher grain yield than Darulaman 07 (Table 2). However, it was at par with PBW 154. The higher grain yield in Herat 99 was achieved due to more number of spike m^{-2}, LAI, and dry matter accumulation over other varieties. Saeed et al. (2012) also reported significant differences among the varieties for grain yield.

Straw yield significantly varied among the varieties. Straw yield was significantly higher in Herat 99 compared to Darulaman 07 but was at par with PBW 154. Straw yield of wheat is the function of an accumulated effect of growth parameters like tillers per unit area, LAI and final height. Thus in Herat 99, higher straw yield was attributed mainly to higher values of growth parameters. These results are in conformity with the findings of Gawali et al. (2015) who reported straw yield of wheat was affected significantly by the different varieties. Biological yield showed significant variations under different varieties. Again, variety Herat 99 showed higher biological yield compared to other varieties (Table 2). In Herat 99, the higher biological yield was supported by relatively greater plant height, higher number of tillers and higher number of leaves per unit area. Shirazi et al. (2014) have also reported significant variation in biological yield among different wheat varieties. Harvest index is the ratio of grain yield to biological yield. The result of this study showed that there were non-significant differences found among different varieties for harvest index (Table 2).

Effect of row spacing

The results of the investigation showed that different row spacing significantly influenced the grain yield of wheat. Numerically higher grain yield was recorded from 20 cm row spacing than 30 cm (Table 2). The higher grain yield in 20 cm row spacing was achieved mainly due to more number of spike per square metre over other row spacings. The finding is in conformity with findings of Kalpana et al. (2014) who reported that grain yield increased as row spacing decreased.

Straw yield showed significant differences under different row spacing. Higher straw yield was recorded with 20 cm row spacing as compared to 30 cm row spacing (Table 2). This was closely followed by 25 cm row spacing (Table 3). This higher straw yield in 20 cm and 25 cm row spacing occurred mainly due to higher number of tillers, greater leaf area index and plant height. Such finding were supported by Ali et al. (2010) who reported that narrow row spacing recorded higher straw yield than wider row spacing.

Biological yield obtained from 20 cm row spacing was higher as compared to 30 cm row spacing (Table 2). Higher biological yield in 20 cm row spacing resulted from relatively higher plant height, higher number of tillers and higher leaves per unit area. These findings are in agreement with the findings of Mali and Choudhary (2011) who reported that biological yield was significantly higher in 20 cm as compared to 17.5 and 15 cm row spacing and were at par with 22.5 cm. The result of this study showed that there were non-significant differences among different row spacing for harvest index (Table 2). Similarly, non-significant effect of row spacing on harvest index was reported by Bakht et al. (2007).

Table 2. Yield and harvest index of different wheat (*Triticum aestivum* L.) varieties as influenced by variable row spacing in semi-arid region of Kandahar

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Varieties				
PBW 154	3.61	5.75	9.36	38.4
Darulaman 07	3.38	5.47	8.85	38.2
Herat 99	3.71	6.17	9.88	37.7
SEm (±)	0.053	0.142	0.152	0.62
CD (P=0.05)	0.160	0.426	0.456	NS
Row spacing (cm)				
20	3.73	6.00	9.73	38.3
25	3.64	5.96	9.60	37.9
30	3.33	5.43	8.76	38.0
SEm (±)	0.053	0.142	0.152	0.62
CD (P=0.05)	0.160	0.426	0.456	NS

Efficiency indices

Effect of varieties

The result of this study showed that production efficiency was significantly higher with variety Herat 99 (28.8 kg ha^{-1} per day) in comparison to Darulaman 07, but was at par with PBW 154 variety (Table 3). The higher PE in Herat 99 could be due to higher grain yield of this variety.

The significantly higher value of irrigation water-use efficiency (IWUE) was registered with Herat 99 as compared to Darulaman 07. But the difference between variety Herat 99 and PBW 154 were found at par with each other (Table 3). The higher IWUE in Herat 99 was mainly due to higher grain yield of Herat 99 variety as amount of irrigation water used for each variety was equal.

Energy relations of wheat varieties under various row spacing are given in (Table 3). Results showed that Herat 99 wheat variety had significantly higher output energy (131,709 MJ ha^{-1}) compared to PBW 154 and Darulaman 07. This difference might be due to higher biological yield of the particular Herat 99 variety. Likewise, higher energy use efficiency (7.5) was recorded in Herat 99 than other varieties (Table 3). The difference in energy use efficiency might be due to higher grain yield of Herat 99 variety as amount of input energy for each variety was equal.

Effect of row spacing

Table 3 revealed that 20 cm row spacing resulted in significantly higher production efficiency (28.9 kg ha^{-1} per day) as compared to 30 cm row spacing. Production efficiency recorded with 25 cm row spacing was also significantly higher than 30 cm row spacing, higher production efficiency (PE) in narrow row spacing was due to significantly higher grain yield, at narrow row spacing.

The significantly higher irrigation water-use efficiency (IWUE) was registered with 20 cm row spacing than 30 cm row spacing. But the difference between 20 cm and 25 cm row spacing was non-significant (Table 3). The higher IWUE at 20 cm row spacing was mainly due to higher grain yield. These results are in agreement with the finding of Hussain et al. (2016) who reported narrow spacing (20 cm) resulted in efficient use of available irrigation water with higher yield. Similarly, Kleemann and Gill (2010) reported that there was a consistent decline in water-use efficiency for grain (WUE_G) with increasing row spacing.

Row spacing of 20 cm showed significantly better performance than 30 cm row spacing (129,803 MJ ha^{-1}) regarding output energy (Table 3). It could be due to higher grain and straw yield production from the mentioned planting geometry. Likewise, 20 cm row spacing recorded significantly greater energy use efficiency (7.4) than 30 cm row spacing which were statistically at par with 25 cm row spacing (Table 3). These findings showed that the energy use efficiency increased linearly as the row spacing decreased. These findings may be due to high biomass production of the concern row spacing.

Table 3. Efficiency indices and economic of different wheat (*Triticum aestivum* L.) varieties as influenced by variable row spacing in semi-arid region of Kandahar

Treatment	PE (kg ha^{-1} per day)	Irrigation WUE (kg ha^{-1}mm^{-1})	Output energy (MJ)	Energy use efficiency	Gross return (Afn. ha^{-1})	Net return (Afn. ha^{-1})	B: C ratio
Varieties							
PBW 154	28.0	10.3	124,953	7.1	165,789	111,892	2.1
Darulaman 07	26.2	9.7	118,068	6.7	156,167	102,770	1.9
Herat 99	28.8	10.6	131,709	7.5	173,078	119,681	2.2
SEm (±)	0.41	0.15	1,947	0.33	2,148	2,148	0.04
CD (P=0.05)	1.24	0.46	5,838	0.11	6,439	6,439	0.12
Row spacing (cm)							
20	28.9	10.7	129,803	7.4	171,878	118,231	2.2
25	28.2	10.4	128,036	7.3	168,822	115,176	2.1
30	25.8	9.5	116,891	6.6	154,333	100,937	1.9
SEm (±)	0.41	0.15	1,947	0.33	2,148	2,148	0.04
CD (P=0.05)	1.24	0.46	5,838	0.11	6,439	6,439	0.12

Economics

Effect of varieties

Economics of production is very important aspect to judge the efficiency of different production system based on physical feasibility and its commercial viability, economics determination, cost of cultivation, gross returns, net returns and B: C ratio. The compatibility of different treatments was worked out with a view to understanding its feasibility and economic viability in a given system.

In the current study, Herat 99 variety showed significantly higher gross and net returns than other varieties (Table 3). Higher gross and net returns of Herat 99 were mainly due to its higher grain and straw yield than other varieties. Similar findings were also observed by Pyare et al. (2015) who revealed significant differences among wheat varieties for gross income, net income and return per Afn.

The significantly higher value of benefit: cost ratio was registered in Herat 99 than Darulaman (Table 3) due to same cost of production but higher net returns in this variety.

Effect of row spacing

Significantly higher gross and net returns of wheat were recorded with 20 cm row spacing followed by 25 cm row spacing (Table 3). The higher gross return was mainly due to higher grain and straw yields of wheat in the respective row spacing. Similar findings were also observed by Ahmad et al. (2003) who reported maximum grain yield, and net income were found in 20 cm than 30 and 40 cm row spacing. Similarly, Marwat (2003) reported that maximum net returns in wheat were obtained when sown at closer spacing of 18 cm.

Benefit: cost ratio of wheat sown at 20 cm row spacing was higher than B:C ratio observed with 30 cm row spacing (Table 3). The higher benefit: cost ratio in 20 cm row spacing was due to almost same cost of production but higher net returns. Mali and Choudhary (2011) also reported that 20 cm row spacing recorded significantly higher net returns and B: C ratio over other row spacing. Also, Kaur et al. (2015) reported that B: C ratio in bi-directional sowing and closer sowing was significantly better than 20 cm spacing.

CONCLUSION

After going through the finding of the present study, it was concluded that variety Herat 99 was superior in yield, efficiency indices and economic as compared to other varieties. Decreasing row spacing consecutively improved the yield, efficiency indices and economic of wheat; and 20 cm row spacing resulted in maximum yield ha^{-1} and benefit cost ratio. Therefore, Herat 99 variety sown in 20 cm row spacing is recommended for sowing to farmer community at Kandahar province.

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