

## EFFECT OF SEED RATE AND ROW SPACING ON GRAIN YIELD OF SORGHUM

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### ABSTRACT

An experiment to investigate the effect of seed rate (5, 7.5, 10, 12.5 and 15 kg ha<sup>-1</sup>) and row spacing (30, 45 and 60cm) on agronomic characteristics of plants including stem density m<sup>-2</sup>, plant height, stem diameter, number of heads m<sup>-2</sup>, number of heads per plant, number of grains per head, 1000-grain weight and grain yield was conducted using the cultivar "Sorghum 2011" for two years 2016 and 2017. Seed rates and row spacing had significant effect on plant height, plant density m<sup>-2</sup>, number of heads m<sup>-2</sup>, number of grains per head and grain yield. Row spacing had non-significant effect on stem diameter, number of heads per plant and 1000-grain weight. Row spacing at 30 cm produced the highest number of plants m<sup>-2</sup> and plant height. Plant height increased with increase in seed rate in all the row spacing. Stem diameter decreased with increase in the seed rate and row spacing. Narrow row spacing (30 cm) and low seeding rate (5 kg ha<sup>-1</sup>) produced the maximum grain yield consistently during both years. Lower yields were recorded in the treatments having greater row spacing (60 cm) and higher seed rates (7.5, 10, 12.5 & 15 kg ha<sup>-1</sup>). Higher seed rates and wider row spacing induced morphological changes rendering plants to lodging.

**Keywords:** Sorghum bicolor, seed rate, row spacing, grain yield.

### INTRODUCTION

Seed rate and row spacing are important factors for crop establishment technique that affects the crop stand and other yield parameters in different crops. Maintenance of optimum planting density is always a big problem to the farmers. Lower plant density results in higher weed infestation, poor radiation use efficiency and lower yields. On the other hand, dense plant population may cause lodging, poor light penetration in the canopy, reduction of photosynthesis due to shading of lower leaves and serious reduction in the yield (Lemerle et al., 2004; Lemerle et al., 2006). Similarly, plant population, on the basis of row spacing and seed rate, affects the crop stand,

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agronomic plant characteristics and the yield in sorghum crop (McMurray, 2004; McRae et al., 2008).

Tillering is an important morphological component of grain sorghum (*Sorghum bicolor* L. Moench) development because it affects light capture, water use, grain yield, plant competition and other physical and biological processes (Krishnareddy et al., 2006). It has also been reported that increase in plant population results in decrease in number of tillers (Pawlowski et al., 1993; Caliskan et al., 2007), plant height (Ayub et al., 2003) and stem diameter (Caravetta et al., 1990) but grain yield per unit area increased (Caliskan et al., 2007).

Row spacing affects the crop yield potential (Staggenborg, 1999; Bryant et al., 1986). Reducing the distance between rows improves weed control (Walker & Buchanan, 1982) by increasing crop competition and reducing light transmission to the soil (Andrade et al., 2002). Narrow row spacing results in higher grain yields in soybean (De Bruin & Pederson, 2008) and in other crops (Stickler & Laude, 1960). Narrow row spacing resulting in higher yield is explained by the improved light interception (Steiner, 1986) and decreased plant to plant competition between plants (De Bruin & Pederson, 2008). Johnson et al. (2005) reported reduction in total weed density in 30cm apart rows of peanut (*Arachis hypogea*) as compared to the weed density at greater spacing.

Grain sorghum is commonly cultivated in rows with 60 to 75cm spacing, but with the development new production technology and introduction of new herbicides has opened a new window of opportunity to test narrower row spacing for grain production of sorghum. Determining the optimum seed rate is essential to get the proper crop stand and maximum yield (Cox, 1996; Widdicombe & Thelen, 2002) of sorghum crop. The aim of this research was to study the effect of seed rate and row spacing on different attributes of sorghum in order to get maximum grain yield of sorghum crop.

## MATERIALS AND METHODS

This study was conducted at experimental field of Fodder Research Institute (FRI), Sargodha, Pakistan during the years 2015 and 2016 to investigate the proper seed rate with relation to row spacing of new variety "Sorghum 2011". The experiment was laid out in split plot design keeping row spacing (30, 45 & 60 cm apart) in main plots and seeding rate (5, 7.5, 10, 12.5 & 15 kg ha<sup>-1</sup>) in sub-plots measuring 2.7m x 5m with three replications. The experiment was sown on 2<sup>nd</sup> week of July during both years. Sowing was done with the help of hand drill. First irrigation was given after 25 days of sowing. The subsequent irrigations were adjusted according to the climatic conditions and need of the crop. Fertilizer @ 57-57-57 NPK kg ha<sup>-1</sup> was applied during both years.

Data on plant height, stem diameter, stem density (number of plants) $m^{-2}$ , number of heads $m^{-2}$ , number of heads plant $^{-1}$ , numbers of grains head $^{-1}$ , 1000-grain weight and grain yield  $ha^{-1}$  were recorded.

The trend of data collected during two years was found similar. So, the data were averaged. The data averaged on two years were analyzed statistically and differences among the treatment means were compared by using the least significant difference (LSD) test at 0.05 probability level with the help of M-Stat C programme.

### RESULTS AND DISCUSSION

Significant differences among row spacing, seed rates and interaction of both the variables were found for number of grains per head, number of heads $m^{-2}$ , stem density  $m^{-2}$  and stem diameter in the combined results of two years (Table 1).

Plant height increased with increasing seed rate and decreasing row spacing. The combined effect of row spacing and seed rate, the interaction, had no effect on plant height (Table 1). Snider et al. (2012) also reported the effect of seeding rate on the plant height to be significant but contrasting effects at different sites. Higher seeding rate may stimulate plant height due to internode elongation (Schmitt & Wulff, 1993). The results indicated that besides genetic constitution, row spacing and seed rate also control growth behavior of sorghum plant. Data also revealed that plant height decreased with increased row spacing and decreased seed rate that probably due to plant competition for light. The maximum plant height 313.11cm was recorded with seed rate of 15  $kg\ ha^{-1}$  while maximum plant height (309.87cm) was recorded at 30cm row spacing. Similar results of row spacing on plant height have been reported by others (Srivastava et al., 1980; Rana and Ahuja, 1986).

Stem diameter was affected by seeding rate but row spacing had no effect on stem diameter (Table 1). Increase in seed rate from 5  $kg\ ha^{-1}$  to 15  $kg\ ha^{-1}$  resulted in a significant decrease in stem diameter while increased the stem density. This is due to the fact that higher seed rate directly results in higher stem density and a higher stem density resulting in decrease in stem diameter due to the obvious interplant competition (Schmitt & Wulff, 1993; Van Der Werf et al., 1995). Higher plant density produces thin stemmed plants that tend to lodge (Kashiwagi et al., 2008; Venuto & Kindiger, 2008) and high seeding rates should be avoided for sorghum in regions where lodging is a major concern. The effect of interaction between seeding rate and row spacing on stem diameter was significant (Figure 1). No significant effect of increasing the row spacing within a given seed rate was recorded on the stem thickness, however at the highest seed rate (15  $kg\ ha^{-1}$ ), the stem thickness decreased significantly as the row spacing increased to 60cm. The maximum stem diameter (1.88cm) was recorded from the treatment interaction of the lowest seed rate (5  $kg\ ha^{-1}$ ) with the least row spacing (30cm) and the interaction of statistically similar stem thickness (1.88cm) from the interaction of the lowest seed rate (30cm) and wider row spacing (45 & 60cm).

Table 1. Effect of seeding rates and row spacing on yield and yield components of sorghum (2-year average)

Treatments	Plant Height (cm)	Stem Diameter (cm)	Stem Density m <sup>2</sup>	No. of Heads m <sup>2</sup>	No. of Headsplant <sup>-1</sup>	1000-grain Weight (g)	No. of Grains head <sup>-1</sup>	Grain Yield (kg ha <sup>-1</sup> )
SR <sub>1</sub> (5 kg ha <sup>-1</sup> )	281.67e	1.88a	25.44e	21.22e	0.843 a	17.14 a	1020.6a	2996 a
SR <sub>2</sub> (7.5 kg ha <sup>-1</sup> )	291.22d	1.82b	31.11d	25.00 d	0.803 ab	16.76 b	797.2b	2766 b
SR <sub>3</sub> (10 kg ha <sup>-1</sup> )	297.44c	1.78c	40.33c	31.22 c	0.774 bc	16.21 c	648.0c	2557 c
SR <sub>4</sub> (12.5 kg ha <sup>-1</sup> )	308.67b	1.73d	51.67b	38.11 b	0.738 cd	15.81 d	536.0d	2357d
SR <sub>5</sub> (15 kg ha <sup>-1</sup> )	313.11a	1.60e	59.67 a	42.67 a	0.716 d	15.18 e	489.4e	2329d
<i>LSD (0.05)</i>	<i>3.374</i>	<i>0.021</i>	<i>2.099</i>	<i>2.112</i>	<i>0.0497</i>	<i>0.133</i>	<i>35.27</i>	<b><i>141.49</i></b>
RS <sub>1</sub> (30 cm)	309.87a	1.78	43.60a	33.27a	0.781	16.28	757.9 a	2747 a
RS <sub>2</sub> (45 cm)	297.40b	1.76	41.00b	30.40 b	0.761	16.21	693.7 b	2622 ab
RS <sub>3</sub> (60 cm)	288.00c	1.75	40.33b	31.27b	0.783	16.16	643.1 c	2433 b
<i>LSD (0.05)</i>	<i>4.670</i>	<i>NS</i>	<i>1.894</i>	<i>1.753</i>	<i>NS</i>	<i>NS</i>	<i>25.62</i>	<b><i>222.86</i></b>
RS <sub>1</sub> SR <sub>1</sub>	296.00	1.88 a	23.33g	19.67g	0.830	17.22	1157.7a	3257
RS <sub>1</sub> SR <sub>2</sub>	302.00	1.83 bc	30.33 f	24.67 f	0.809	16.88	880.0c	2983
RS <sub>1</sub> SR <sub>3</sub>	310.00	1.81 cd	43.67 d	34.33 d	0.787	16.37	662.3ef	2690
RS <sub>1</sub> SR <sub>4</sub>	320.00	1.73 ef	55.67 b	42.33 ab	0.760	15.85	579.7gh	2417
RS <sub>1</sub> SR <sub>5</sub>	321.33	1.64 f	65.00 a	45.33a	0.697	15.11	510.0i	2390
RS <sub>2</sub> SR <sub>1</sub>	280.00	1.88 ab	26.67g	22.00g	0.840	17.17	997.0b	2980
RS <sub>2</sub> SR <sub>2</sub>	290.00	1.82 c	32.00f	25.33 f	0.790	16.72	798.3d	2793
RS <sub>2</sub> SR <sub>3</sub>	295.00	1.77 de	37.33 e	30.00 e	0.803	16.14	655.0ef	2650
RS <sub>2</sub> SR <sub>4</sub>	308.33	1.72 f	51.33 c	34.67 d	0.677	15.78	528.3hi	2376
RS <sub>2</sub> SR <sub>5</sub>	313.67	1.61 f	57.67 b	40.00 bc	0.693	15.25	490.0i	2310
RS <sub>3</sub> SR <sub>1</sub>	269.00	1.88 a	26.33g	22.00g	0.840	17.04	907.0c	2750
RS <sub>3</sub> SR <sub>2</sub>	281.67	1.81 cd	31.00 f	25.00 f	0.810	16.67	713.3e	2520
RS <sub>3</sub> SR <sub>3</sub>	287.33	1.77 de	40.00 de	29.33 e	0.777	16.12	626.7fg	2330
RS <sub>3</sub> SR <sub>4</sub>	297.67	1.73 ef	48.00c	37.33 cd	0.757	15.80	500.0i	2277
RS <sub>3</sub> SR <sub>5</sub>	304.33	1.55 g	56.33 b	42.67ab	0.733	15.17	468.3i	2287
<i>LSD (0.05)</i>	<i>NS</i>	<i>0.044</i>	<i>3.636</i>	<i>3.658</i>	<i>NS</i>	<i>NS</i>	<i>61.10</i>	<i>NS</i>

SR = Seed Rate, RS = Row spacing

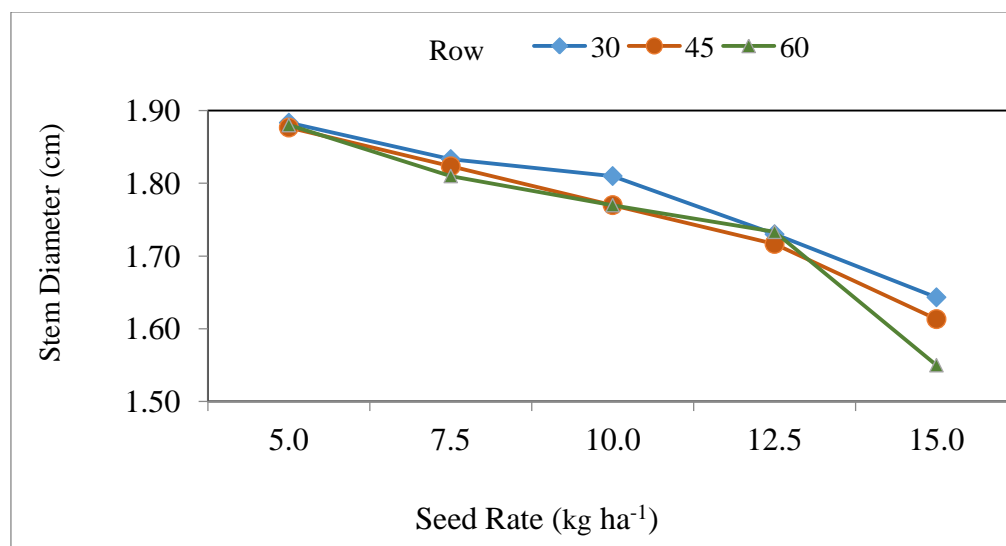


Figure 1. Interactive effect of seed rate and row spacing on stem diameter of sorghum.

Stem density (number of plants  $m^{-2}$ ) was statistically higher in the narrow row spacing (30cm) than those in wider row spacing of 45cm and 60cm. (Table 1). Increase in seed rate from 5 to 15  $kg\ ha^{-1}$  resulted in increased stem density from 25.44 to 59.67 stem  $m^{-2}$ . Interaction between seeding rate and row spacing was significant for stem density (Figure 2). A trend of differences in the stem density due to interaction between seed rate and row spacing was recorded to be more prominent due to different row spacing interaction with the highest seed rate. Among all the interactions, the highest stem density i.e. 65.00 stems  $m^{-2}$  was recorded in the interaction of 30cm row spacing with 15  $kg\ ha^{-1}$  seed rate followed by statistically lower cluster of stem density in the decreasing trend (57.67, 56.33 & 5.67 stems  $m^{-2}$ ) in the interactions of 45cm row spacing and seed rate of 15  $kg\ ha^{-1}$ ; 60cm row spacing and seed rate of 15  $kg\ ha^{-1}$ ; and 30cm row spacing and seed rate of 12.5  $kg\ ha^{-1}$ . All the other interactions resulted in further statistically different and lower stem density clusters with the least stem density in three interactions of 60cm, 45cm and 30cm at 5  $kg\ ha^{-1}$  seed rate having 21.00, 20.67 and 19.67 stem densities in the decreasing trend, respectively. Similar results have been reported by Snider et al. (2012) stating that plant stand establishment may be more favorable under narrow row spacing as compared to wider row spacing i.e. 76cm row spacing, owing to more number of seeds per length of row resulting in increased intra-row competition among plants during the early plant establishment. Such observations have been recorded for other crop species as well (De Bruin & Pedersen, 2008) suggesting decrease in the plant population by increasing row spacing caused by the intra-row competition between plants.

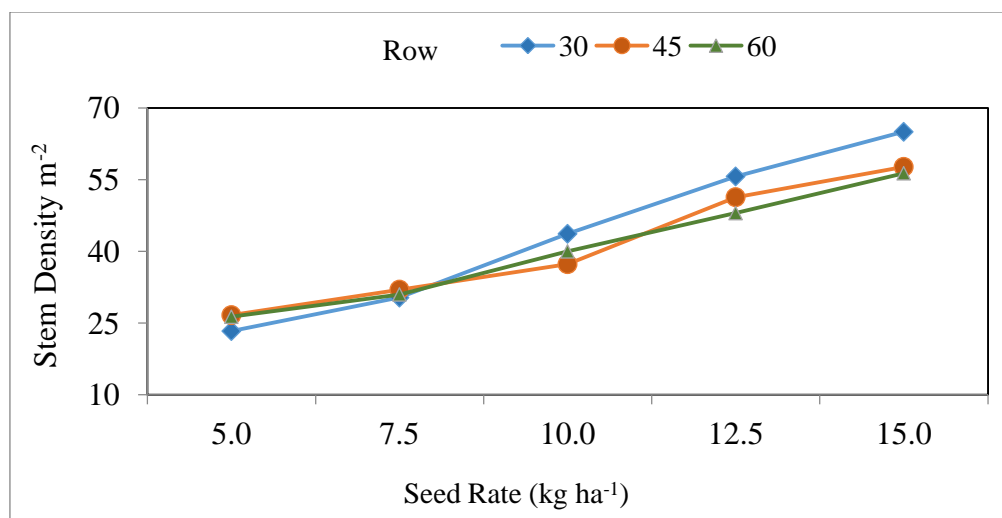


Figure 2. Interactive effect of seed rate and row spacing on density m<sup>-2</sup> of sorghum

The trend of number of viable heads m<sup>-2</sup> was similar to that of stem density (Table 1). All treatments of seed rate differed significantly from each other for their effect on the number of viable heads m<sup>-2</sup>, producing the highest number of viable heads m<sup>-2</sup> (42.67) in the highest seed rate decreasing with the decrease in the seed rate. This behavior is due to the fact that using the highest seed rate at the narrow row spacing (30cm) would accommodate more number of lines resulting in greater plant to plant distance within the row providing more space to the individual plants for their establishment. Mascagni & Bell (2005) also reported that there had been more tillering for twin rows since the intra-row spacing was greater than the single row for a given seeding rate. The result of number of heads m<sup>-2</sup> had no effect on sorghum grain yield ha<sup>-1</sup> and this behavior of sorghum crop is supported by the studies of Mascagni & Bell (2005). The interaction between spacing and seed rate was significant for its effect on the number of viable head m<sup>-2</sup> (Figure 3). The percentage of head formation on plants was affected significantly with varying the seed rate showing an overall trend of decrease in head formation as the seed rate was increased. The highest percentage of head formation (83.41%) was recorded at 5 kg seed ha<sup>-1</sup>, having 254,400 plants ha<sup>-1</sup>, followed by statistically similar 7.5 kg seed ha<sup>-1</sup>, having 311,100 plants ha<sup>-1</sup>, producing heads on 80.36% plants. A further decrease of head formation was recorded as the seed rate increased (Table 1). In case of two lower seed rates i.e. 5 kg ha<sup>-1</sup> and 7.5 kg ha<sup>-1</sup>, the intra-row spacing was greater than the higher seed rate and the production of higher percentage was recorded due to the phenomenon explained earlier as for the establishment of plants. Earlier studies have reported that a single row planting, having 124,000-160,000 plant ha<sup>-1</sup>, produced a greater number of heads plant<sup>-1</sup> than the twin row planting at any population (Fernandez et al., 2012). They also reported that 76cm row spacing planted 210,000

to 240,000 plants ha<sup>-1</sup> produced the greatest number of heads per plant than the lower plant population at 76cm row spacing. The results of the current studies are in agreement with the earlier studies reported.

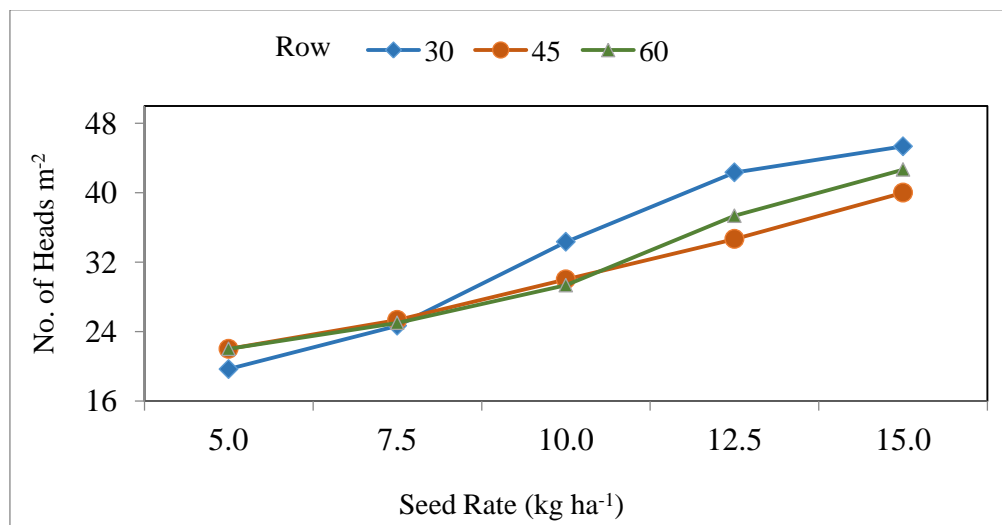


Figure 3. Interactive effect of seed rate and row spacing on number of heads m<sup>-2</sup> of sorghum.

The effect of row spacing on 1000-grain weight did not differ significantly. On the other hand, seed rates affected 1000-grain weight significantly showing a continuous trend of reduction in the 1000-grain weight as the seed rate was increased. The highest 1000-grain weight of 17.14 g was recorded at 5 kg ha<sup>-1</sup> seed rate (Table 1). The parameter of increase in 1000-grain weight was reflected in the grain yield increase confirming its contributive factor for grain yield. This study was supported by Fernandez et al. (2012) reporting that the single-row planting at low plant population produced the highest grain weight.

Number of grains per head plays an important role in grain yield of sorghum crop. In the present study, all seed rates were significantly different, producing the highest number of grain per head (1020.6) in the 5 kg seed ha<sup>-1</sup>. Similarly, closer row spacing (30cm) produced the highest number of grain per head (757.93). The results of the interaction between seed rate and row spacing depicted that the lowest 5 kg seed ha<sup>-1</sup> with narrow row spacing of 30cm was the best combination, producing 1157.7 grains per head (Table 1). At all three row spacings, number of grains per head decreased with the increase of seed rate (Figure 4). While at all five seed rates, number of grains per head decreased with increase of row spacing (Figure 4). The increase in number of grains per head by using different seed rates, row spacing or the geometry of sowing pattern has been attributed basically due low plant population or more plant to plant distance (Fernandez et al., 2012). The number of seed per head plays an important role in yield determination and has been reported to contribute

70% towards grain yield sorghum as reported by Karchi & Rudich (1966). The current study was in confirmation of number of grains per head playing a major contributive role towards grain yield of sorghum.

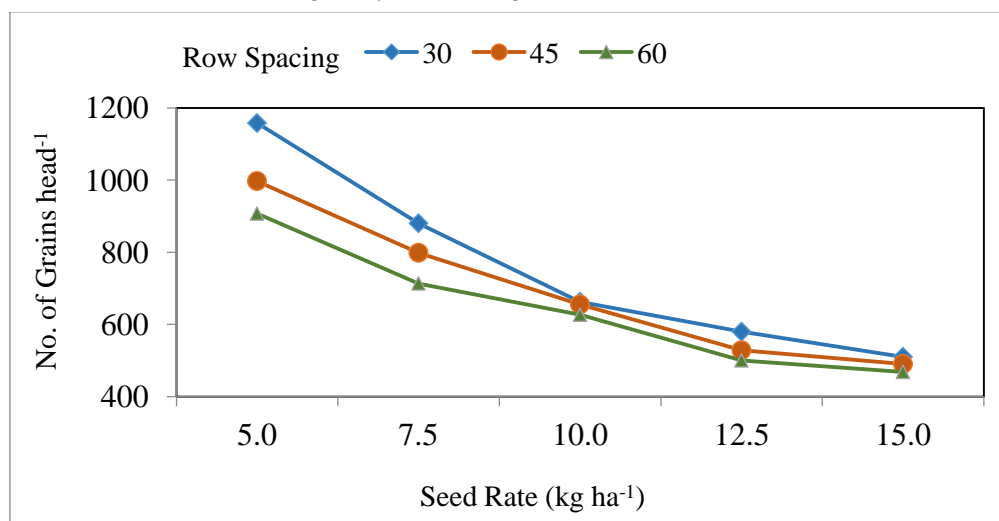


Figure 4. Interactive effect of seed rate and row spacing on number of grains head<sup>-1</sup> of sorghum

The maximum grain yield (2747 kg ha<sup>-1</sup>) was obtained with row spacing at 30 cm that was statistically at par with that of 45cm apart row (2622 kg ha<sup>-1</sup>) but significantly higher than the grain yield (2433 kg ha<sup>-1</sup>) obtained from row spacing at 60 cm apart (Table 1). Similar response to row spacing has been reported in previous studies where similar row spacing produced higher yields of sorghum grains (Stickler & Laude, 1960; Steiner, 1986), forage (Stickler & Laude, 1960) and other crops such as soybean (De Bruin & Pedersen, 2008). Higher biomass production of sorghum crop with a narrower row spacing of 19cm has been mentioned by Snider et al. (2012), and the phenomenon might be due to the better light interception (Steiner, 1986) and decreased inter-row competition between plants (De Bruin & Pederson, 2008). In contrast, the seed rate studies showed constant decrease in the grain yield with increase in the seed rate (Table 1). Snider et al. (2012) have reported a significant yield reduction with increase in seeding rate from 218,000 to 393,000 ha<sup>-1</sup>; however the seeding rate 116,000 to 291,000 ha<sup>-1</sup> did not affect the yields. Higher seed rates have been reported as to increase dry matter production but, in other cases on the contrary, no such effect has been reported to showing inconsistency (Habyarimana et al., 2004; Wortmann et al., 2010). According to the current studies, 30 cm row spacing and 5 kg seed ha<sup>-1</sup>, requiring the least inputs, were found to be the optimum, among the tested seed rates and row spacing levels, for better above-ground biomass and yield of the cultivar “Sorghum 2011” (Table 1). These findings



suggests a phenomenon that for any given seed rate tested better crop stand can be established by 30cm apart row spacing as compared to other row spacing. This behavior might be attributed to the fact that at wider row spacing of 60cm, each row would receive a higher number of seeds, increasing the number of plants per row, and the intra-row plants would suffer from increased plant-to-plant competition during the early plant establishment stage. Similar results have been depicted from other studies as well in other crops (De Bruin & Pederson, 2008).

These studies indicated consistent increase in plant density  $m^{-2}$  with increase in the seed rate in sorghum cultivar "Sorghum 2011". Such increase in plant population by increasing the seed rate has been reported by other workers (Geleta et al., 2002; Habyarimana et al., 2004; Wortmam et al., 2010) and an interplant competition has been reported to have pronounced effect leading to self-thinning at higher seeding rates of some species (Van Der Werf et al., 1995 ) decreasing the yield.

### CONCLUSIONS

Increasing the seed rate from  $5 \text{ kg ha}^{-1}$  ( $254,400 \text{ plants ha}^{-1}$ ) to higher seed rates, the grain yield decreased significantly. Higher grain yield in sorghum cultivar sorghum 2011 was recorded under narrower row spacing of 30-45 cm. Row spacing primarily influences the number of plants  $m^{-2}$  (stem density  $m^{-2}$ ) and results of the grain yield are considered to be more dependent, or attribute of, plant to plant space using seed rate, row to row distance, different establishing techniques or the planting geometry etc. The present study indicates that the plant characters such as stem diameter and plant height are affected by the plant population, depending upon the seed rate or the plant spacing, where stem diameter was negatively affected, while the plant height was positively affected, with increase in the seed rate. Both the parameters are, in common observation, are affected oppositely as plant height or tiller height increases, the stem diameter decreases. Seed rate and spacing effect was recorded to enhance one of the above parameter and had the contrary effect on the other. Higher seed rate or wider row spacing, within a given seed rate giving more number of plants per row, produces thinner plants that are more vulnerable to lodging. The plant characteristics such as stem diameter, density  $m^{-2}$ , number of heads per plant and number of grains per head were inferred to be improved in the treatment combination of lowest seed rate and 30cm row spacing, and the same combination producing better sorghum grain yield. Hence,  $5 \text{ kg ha}^{-1}$  seed rate of Sorghum with 30cm row spacing is considered to be the optimum for higher grain yield.

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