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Contribution of fertilizer levels and seed rate on production and yield attributes of Sorghum

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Abstract

Sorghum (*Sorghum bicolor* L. Moench.) is a popular summer fodder and cereal crop in Pakistan. Unawareness of farmers regarding fertilizer level and seed rate effect the optimum crop production. A study was carried out to optimize the fertilizer levels and seed rate for economical production. Response of fertilizer levels of P_2O_5 & K_2O (20-20, 40-40 and 60-60kg ha^{-1}) with constant level of N 57kg ha^{-1} and seed rates (5, 7.5, 10, 12.5 & 15kg ha^{-1}) on fodder and grain yield of sorghum (Sorghum 2011) was studied during Kharif 2016 and 2017. It was found that fertilizers (P_2O_5, K_2O) levels and seed rate had significant impact on plant height, diameter of stem, 1000 grain weight, grains head^{-1} and yield of grain but no significant impact was observed on number of tillers m^{-2} and head m^{-2}. The study revealed that maximum grain yield (2816kg ha^{-1}) was achieved with the lowest seed rate (5kg ha^{-1}) and PK fertilizer dose of 40-40kg ha^{-1} along with constant dose of nitrogen at the rate of 57kg ha^{-1}, while doses (20-20 and 60-60 PKkg ha^{-1}) for P_2O_5 and K_2O respectively with seed rate of 7.5kg ha^{-1} was found statistically similar. Further, maximum number of plants m^{-2} and height of plant was achieved under seed rate of 15kg ha^{-1}. It was observed that height of plant increased in all levels of fertilizers and stem diameter decreased gradually by increasing seed rate, however, stem diameters was increased by increasing fertilizer but it caused morphological changes resulted in plants lodging.

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Introduction

Sorghum (*Sorghum bicolor L.*) ranks fifth number in cereal crops, with an annual production of 60 million tons worldwide. It is grown in Pakistan on 255,000 hectares, with a production of 154,000 tons annually with mean yield of 603.92kg ha^{-1} (Pak. Economic Survey, 2017-18). Sorghum plays substantial role in providing raw material for agro-base industry (starch, dextrose syrup, fiber and other goods) as well as essential for food, feed, and forage. Sorghum is grown in semiarid zone (more than half of the world) as primary food for millions of poor communities (Mehmood *et al.*, 2008). Local name of sorghum in Pakistan is Jawar, the main Kharif crop and which is sown for both forage and grain purposes. Sorghum is an essential feed for livestock as a summer fodder which helps to maintain good animal's safety. Sorghum feed comprises more than 50 percent edible nutrients containing 8 percent protein, 2.5 percent fat and 45 percent nitrogen free extract. Beside grains, sorghum Stover and fresh fodder is an important food for dairy animals in the live-stock sector. Therefore, dual purpose (Grain and Stover) sorghum is preferred among farming community (Kelley and Rao, 1994; Hall and Yoganand, 2000).

Seed rate and fertilizer level are important factors for crop production technique in agronomic studies that affect production and yield attributes of sorghum. To maintain a proper crop stand is a main issue of farmers. The consequences of the lower plant population, higher weed infestation, loss of soil moisture through evaporation and poor photosynthesis lead to lower yield. While, dense crop stand may induce severe competition for nutrients, moisture and cause lodging, poor penetration of light, decreased photosynthesis and extreme losses in yield (Lemerle *et al.*, 2004 and 2006). Mc Murray 2004; Mc Rac *et al.*, 2008 reported that crop stand is adversely affected by improper row spacing and rate of seed. Tillers per unit area is a significant morphological aspect of grain and fodder sorghum production because they have an effect on light acquisition, water usage, grain and fodder yield, competitiveness and other processes within plant system (Krishnareddy *et al.*, 2010).

The soil having low inherent fertility is considered as the most important limitation to food security (Bationo *et al.*, 1998). The main cause of fertility loss in such soil is the mismatch created by nutrients which are not usually replaced after their removal (Gichuru *et al.*, 2003). Sanchez *et al.*, 1997 have assessed depletion of nutrients NPK (22, 2.5, 15kg ha^{1} per annum) respectively after sampling 200 million hectares of cropped area.

Under a continuous crop system inherently infertile soil, external inputs of fertilizers and materials are required to maintain fertility and productivity (Nyathi and Campbell., 1995). Land degradation is considered to be the basic cause of declining nutrients under small holdings (Stoorvogel and Smaling, 1990; Smaling *et al.*, 1997) and fertility imbalance on large scale farming (Nandwa and Bekunda, 1998).

Productivity enhancement is essential to cater for the needs of increasing population. It is hypothesized that better management of nutrient and plant population can play a main role in yield increasing per unit area. However, over-fertilization and under-fertilization result in economic losses and an excessive amount of nitrate nitrogen discharge through washing (Henke *et al.*, 2007). Grain yield of sorghum is affected greatly by the seeding rate and the supply of nutrients but the information on the optimum and economical dose of P_2O_5, K_2o and proper seed rate for higher grain yield and better quality of sorghum in the rain-fed region is lacking. Proper rate of seed is also vital factor to maximize crop yield.

Over seeding can result excess number of the plants and weak quality of spindly seedling and eventually, decreased production. Healthy crop stand is more desirable as compared to dense crop stand to save the crop from adverse condition. Therefore, it is imperative to determine accurate rate of seed in order to obtain an appropriate crop level and yield (Cox, 1996; Widdicombe and Thelen, 2002). The main objective of this research is to determine the optimum seed rate, balanced nutrients and their reaction on sorghum yield attributes to achieve higher yield.

Materials and methods

Location and Design

This research was conducted at Fodder Research Institute, Sargodha, in Kharif, 2016 &17 to determine optimum rate of seed with balance nutrients K_2O and P_2O_5 of new cultivar ″Sorghum 2011". The trial was conducted in split-plot arrangement with P_2O_5 and K_2O 20-20, 40-40 and 60-60kg ha^{-1} with constant dose of N 57kg ha^{-1}(main-plots) and rate of seed 5, 7.5, 10, 12.5 and 15kg ha^{-1} (sub-plots) in three replications with plot size of 2.7m×5m.

Sowing and Parameters Studied

The Sorghum crop was sown during mid of July during both years. Hand drill was used for sowing of crop at 45cm line to line distance. After 25-30 days of sowing when crop achieved 3-4 leaves, first irrigation was applied. Succeeding irrigations were applied according to the soil moisture and crop requirement. Atrazine herbicide was applied @ 4.25kg ha^{-1} after 1^{st} irrigation in water condition against broad leave weeds and crop was harvested at maturity stage. Data on plant height, stem diameter, stem density, heads m^{-2} and number of heads $plant^{-1}$, were recorded by randomly selecting five plants from each treatment at harvesting stage. Five heads were selected from each plot and subjected to sun drying for twelve days before manual threshing to record 1000 grain weight (g) and number of grains $head^{-1}$. Heads from whole plot were harvested and separately sun dried (g) for 14 days before manual threshing to record the sorghum grain yield ha^{-1}. Weight (g) of 1000 grain was calculated on the basis of random selection of four sample of 1000 grain from each treatment. To record seed yield all the heads of each plot were thrashed separately, measured their weight (kg) and calculated yield tons ha^{-1} by using following equation:

$$\text{Grain yield (t. ha}^{-1}) = \frac{\text{Grain yield (kg)from net plot}}{\text{Area of net plot (m2)}} \times 10000$$

Statistical analysis

The average of all data collected during two years was subjected to statistical analysis despite of analyzing separately because most of the parameters recorded showed similar behavior. MSTAT-C programme was used to compare the treatments through least significant differences (LSD) at probability (P 0.05) (Snedecor and Chocran, 2000).

Results and discussion

Fertilizer levels, seed rate and interaction of the variables showed significant impact on some growth parameters of Sorghum. The impact of fertilizer doses (P_2O_5 & K_2O) and seed rate on different growth parameters and grain yield are discussed separately in the following sections.

Plant Height

Plant height of Sorghum was affected significantly with fertilizer levels, seeding rate and their interactions. It has been observed that PK fertilizer dose @60-60kg ha^{-1} developed significantly maximum height of plants i.e 346cm followed by 330.80cm with dose @ 40-40kg ha^{-1} as compare to the minimum plant height of 311.60cm under the dose of 20-20kg ha^{-1} (Table 2). Asgharipour *et al.*, 2011 have observed, the maximum values of growth parameters i.e. 123.67cm height, 8.06cm diameter of stem and 9.71cm length of panicle were achieved by using 200kg ha^{-1} K_2SO_4 while lowest (113.44cm) height was obtained with control in sorghum. Increase in plant height with the increase of inputs may be attributed due to more vegetative growth that resulted in increased reciprocal shade and inter-nodal elongation. These results confirmed by previous findings (Rafiq *et al.*, 2010). Maximum plant height (356.87cm) was obtained with seed rate of 15kg ha^{-1} as compared to minimum plant height 307.11cm with seed rate of 5kg ha^{-1} (Table 1).

Increase in plant height was observed with increasing seed rate because of competition for light as a result of collective shading effects and also the higher plant population stimulates internode elongation and increased plant height. Gondal *et al.*, (2017) reported that a decrease in plant height was observed by increasing row spacing and decreasing seed rate that could be due to light competition among plants. Yasin *et al.*, (2018) have similar findings of increase in plant height of millet at higher seed rate. The impact of interaction of fertilizer doses of P and K and seeding rate has significant impact on plant height (Table .3).

By partition of this interaction with increase of fertilizer dose such as 20-20 to 60-60kg ha^{-1} of PK. It was also observed that combined effect of PK @ 60-60kg ha^{-1} along with N @ 57kg ha^{-1} and seed rate 15kg ha^{-1} resulted highest plant height (370cm).These results were in line with earlier studies (Bothe *et al.*, 2000), wherein they tested a range of 0-75kg ha^{-1} P_2O_5 that resulted in highest plant height using the higher dose of P_2O_5 (75kg ha^{-1}).

The higher plant height due to higher P_2O_5 levels is considered to be due to its essential constituent of plant tissue that plays a positive role in stem elongation (Kummar and Chandra, 2008, Shahid *et al.*, 2009). Similarly Salama and Sinclair, 1994 reported an increase in plant height with higher K levels than at lower K regime as K improves the plant growth by improving nutrient uptake and efficiency.

Table 1. Contribution of seed rate in seed production and yield attributes of Sorghum.

Treatments (Seed rate)	Plant Height (cm)	Stem Dia. (cm)	No. of Plants m^{-2}	No. of Head m^{-2}	1000 Grain Weight (g)	No. of Grains $head^{-1}$	Grain Yield (Kg ha^{-1})
S1(5kg ha^{-1})	307.11 d	1.9222 a	20.333 e	17.778 f	25.803 a	1402.10 a	2478.00 a
S2(7.5kg ha^{-1})	318.33 c	1.8189 b	29.444 d	23.889 d	25.489 b	1054.20 b	2373.70 a
S3(10kg ha^{-1})	326.67 c	1.7900 c	42.111 c	32.778 c	24.433 c	954.40 c	2240.80 b
S4(12.5kg ha^{-1})	338.44 b	1.6444 d	53.222 b	41.556 b	24.044 d	819.70 d	1969.30 c
S5 (15kg ha^{-1})	356.87 a	1.5367 e	64.222 a	46.556 a	23.056 e	677.80 e	1528.80 d
LSD	10.278	0.0244	1.9282	1.7207	0.2564	58.853	115.97

*Means not having the similar letter significantly differ at 5% level of probability.

Table 2. Contribution of fertilizer levels on grain production and sorghum yield attributes.

Treatment (Fertilizer)	Plant Height (cm)	Stem Dia. (cm)	No. of Plants m^{-2}	No. of Head m^{-2}	1000 Grain Weight(g)	No. of Grains $head^{-1}$	Grain Yield (Kg ha^{-1})
F1(57-20-20 NPKkg ha^{-1})	311.60 c	1.6853 c	41.200	32.590	24.269 b	967.27 b	1938.90 c
F2(57-40-40 NPKkg ha^{-1})	330.80 b	1.7560 b	42.130	32.730	25.193 a	990.67 a	2287.80 a
F3(57-60-60 NPKkg ha^{-1})	346.00 a	1.7860 a	42.260	32.790	24.233 b	987.00 a	2127.7 b
LSD	14.32	0.0266	NS	NS	0.3108	17.893	89.830

*Means not having the similar letter significantly differ at 5% level of probability.

Table 3. Interactive effects of P and K levels and seed rate on seed production and sorghum yield attributes.

Interaction	Plant Height(cm)	Stem Diameter(cm)	No. Of Plants m^{-2}	No. of Head m^{-2}	1000 Grain Weight(g)	No. of Grains $head^{-1}$	Grain Yield (Kg ha^{-1})
F1*S1	286.00 i	1.8500	20.330	16.330	25.477 c	1377	2303.00 cde
F1*S2	295.00 hi	1.7760	30.330	24.660	25.267 c	1022	2242.00 de
F1*S3	311.00 gh	1.7460	43.000	33.660	24.167 e	957	1955.30 fg
F1*S4	320.33 fg	1.5760	52.660	41.660	23.733 e	807	1800.00 gh
F1*S5	345.67 bcd	1.4760	65.000	46.660	22.700 f	673	1394.00 i
F2*S1	312.00 gh	1.9500	20.330	16.660	26.333 a	1396	2816.00 a
F2*S2	323.33 efg	1.8400	28.330	25.660	26.033 ab	1079	2510.00 b
F2*S3	325.67 defg	1.8000	41.000	34.660	25.133 cd	957	2268.00 de
F2*S4	338.33 bcdef	1.6500	54.330	40.660	24.700 d	825	2003.00 f
F2*S5	354.67 abc	1.5400	62.000	46.000	23.767 e	697	1452.30 i
F3*S1	323.33 efg	1.9660	20.330	17.330	25.600 bc	1434	2315.00 bcd
F3*S2	336.67 cdef	1.8400	29.660	24.330	25.167 cd	1061	2369.00 bcd
F3*S3	343.33 bcde	1.8200	42.330	33.000	24.000 e	950	2499.00 bc
F3*S4	356.67 ab	1.7060	52.660	42.330	23.700 e	827	2105.00 ef
F3*S5	370.00 a	1.5900	65.660	47.000	22.700 f	663	1740.00 h
LSD	17.802	NS	NS	NS	0.4441	NS	20

*Means not having the similar letter significantly differ at 5% level of probability.

Stem diameter

Stem diameter was also affected with changing seed rate & fertilizer levels. When the seed rate increased from lowest (5kg ha^{-1}) to higher level (15kg ha^{-1}) as tested under present study, it was observed that the diameter of stem significantly decreased (Table 1) while increase in fertilizer levels of P_2O_5 and K_2O from lowest (20-20kg ha^{-1}) to higher level (60-60kg ha^{-1}) resulted in an increase significantly in the diameter of stem (Table 2). Maximum diameter of stem (1.9222cm) was observed at the minimum seed rate (5kg ha^{-1}) having significantly higher than recorded in other tested seed rates. The lowest stem diameter (1.5367cm) was observed in the highest seed rate (15kg ha^{-1}) (Table2). Fertilizer dose of 60-60 P and Kkg ha^{-1} resulted maximum stem diameter (1.7860cm) while lower levels 20-20 and 40-40kg ha^{-1} of P and K resulted in lower stem diameter (Table2).

The possible explanation of reduction in stem diameters at high densities can be attributed to a reduction in the allocation of assimilates and greater competition within plants. Zand *et al.*, (2013) recorded that as tillers increased in plant density per unit area, stem diameter and days decreased to 50 percent flowering, which was possibly accumulated due to reduced assimilate allocation and increased intra-plant competition. Asgharipour *et al.*, (2011) also recorded that the greatest growth parameters (height of plants, diameter of stem and panicle length) were achieved with application of K2SO4@ 200kg ha^{-1} while lowest were obtained with zero level of K_2SO_4. Interactive effect of fertilizer (P & K) doses and seed rate on stem diameter were non-significant (Table 3). The means data of seed rates and fertilizer (P & K) interaction indicated that the stem diameter increased with increasing of fertilizer levels on same seeding rate. Highest diameter of stem (1.966cm) was recorded at fertilizer level of PK @ 60-60kg ha^{-1} and minimum seed rate 5kg ha$^{-1,}$ while 1.85cm diameter of stem was observed at lowest fertilizer level 20-20 PKkg ha^{-1} at same seed rate (5kg ha^{-1}).

Inter-plant competition caused by higher seed rate or plant population decreased diameter of stem. Hayat *et al.*, (2018) observed that plant height was increased and diameter of stem decreased in maize crop with the increase of fertilizers. Although the study indicated reduction in the stem diameter but coupled with higher dose of P and K the effect was compensated. Xiang *et al.*, (2012) observed that height of plant and stem diameter increased initially but the effect decreased with higher amount of P and K application. Increasing dose of K, the stem diameter increased and lodging rate reduced which conformed the findings of Xiang *et al.*, (2012). Taller plants resulting from a higher seed rate or plant population have thin and slender stem that are more prone to lodging (Yasin *et al.*, 2018, Kashiwagi *et al.*, 2008).

Number of plants m^{-2}

Seed rate had a significant impact on number of plants per square meter. Results of study showed that the number of plants per square meter (i.e., plant density) was increased with increase in seed rate of Sorghum variety (Sorghum 2011. Maximum number of plants (64.22m^{-2}) were observed at higher seed rate (15kg ha^{-1}) and were lowest (20.33m^{-2}) when the seed was applied @ 5kg ha^{-1} (Table 1). Fertilizer levels and interaction of seed rate P & K levels has no significant impact on plant population (Table 2, 3). These findings are similar to that of Yasin *et al.*, (2018) and Wortmann *et al.*, (2010).

Number of Heads m^{-2}

Number of variable heads m^{-2} increased by increasing seed rate (Table 1) while different level of fertilizer (P and K) have no significant impact on variable heads m^{-2} (Table 2). Seed rate treatments differed significantly from each other due to their impact on the number of variable heads m-^{2}, producing the highest number of variable heads m^{-2} (46.55) at the highest seed rate, decreasing with a decrease in seed rate throughout the seed rate range tested. Similar findings were observed by Gondal *et al.*, (2017) who found increase in the number of heads m^{-2} while increasing the seed rate. The interactive impact between rate of seed and fertilizer (P and K) levels were found non-significant for variability of Heads m^{-2} (Table 3).

1000 grain weight

Seed rate and fertilizer levels (P & K) both have significant effect on 1000 grain weight of Sorghum cultivar "Sorghum 2011". All seed rates indicated a continuous trend in reduction of 1000 grain weight while seed rate increased over the entire range of seed rate tested under the study (Table 1). The highest 1000 grains weight (25.803 g) was achieved when seed rate 5kg ha^{-1} was applied. When seed rate was increased from 5kg ha^{-1} to 15kg ha^{-1}, the 1000 grain weight decreased significantly. Similar results were noted by Yasin *et al.*, (2018), who reported that by increasing seed rate from 2.5kg ha^{-1} to 7.5kg ha^{-1}, the 1000 grain weight was decreased in case of pearl millet. The fertilizer (P&K) dose of 40-40kg ha^{-1} showed the maximum weight of 1000 grain while the highest (60-60kg ha^{-1}) and lowest (20-20kg ha^{-1}) dose of P & K resulted in significantly lower weight of 1000 grain (Table 2). These results confirmed by earlier findings of Kamara *et al.*, (2007). Interactive impact of seed rate and fertilizer doses on 1000 grain weight was significant (Table 3). Fertilizer dose of P & K (40-40kg ha^{-1}) produced maximum 1000 grain weight (26.33 g) at lower seed rate (5kg ha^{-1}) that was statistically at par to seed rate 7.5kg ha^{-1} (26.033 g) with the same level of fertilizer.

The result was supported by the findings of Yasin *et al.*, (2018). Thousand (1000) grain weights was main contributing factor for increasing grain yield. Similar, results were observed by Fernandez *et al.*, (2012) who reported that low plant population at single row planting produced the highest grain weight.

Number of grains head^{-1}

It is an established fact that number of grains head^{-1} have crucial role in grain yield of all crops including Sorghum. In present research, fertilizer level and rate of seed both showed significant effect on number of grains head^{-1}. Lower number of grains head^{-1} was observed at high seed rate and vise vers. The highest number of grains head^{-1} (1402.1) were observed at lowest seed rate (5kg) ha^{-1} and lowest number of grains head^{-1} (677.8) were observed at highest seed rate (15kg) ha^{-1}(Table 1). Similarly minimum number of grains head^{-1} (967.27) were observed at lower fertilizer level (20-20kg P K ha^{-1})and higher number of grains head^{-1} (990.67) were observed at higher fertilizer level (40-40kg P K ha^{-1}) (Table 2). The results ties well with previous study of Asgharipour *et al.*, (2011) where use of potassium sulphate showed remarkable differences on yield attributes. When K_2SO_4 was applied @ 250kg ha^{-1}, the number of grain panicle^{-1} of sorghum increased by 50 percent over control (without K fertilizer). Masood *et al.*, (2011) also observed that application of P_2O_5 @ 100kg ha^{-1} resulted in maximum number of grains per cob of maize. Interaction of seeding rate and fertilizer doses on number of grains head^{-1} was non-significant (Table 3).

Grain Yield

Significant differences were noted in yield with the application of various seed rates except the rate of 5 and 7.5kg ha^{-1} that was statistically at par. Generally grain yield decreased by increasing the rate of seed and significantly maximum yield was noted at seed rate of 5 and 7.5kg ha^{-1} 2478 & 2373.7kg ha^{-1} respectively as compared to other treatments of seed rate .(Table 1). These results are in agreements with many other researchers (Yasin *et al.*, 2018, Gondal *et al.*, 2017 and Snider *et al.*, 2012).

Different doses of fertilizer (P & K) significantly affected grain yield. Fertilizer @ 40-40kg ha^{-1} P & K produced maximum yield of grains (2287.8kg ha^{-1}) followed by yield of grain (2127.7kg ha^{-1}) where fertilizer added at 60-60kg ha^{-1} P and K. Minimum grain yield (1938.9kg ha^{-1}) was observed where fertilizer 20-20kg ha^{-1} P and K was applied (Table 2). These results ties well with previous studies of Yasin *et al.*, (2018), Wortmann *et al.*, (2010), Kamara *et al.*, (2007), Habyarimana *et al.*, (2004). Interactive impact of fertilizer (P & K) doses and seeding rate on yield of grains was statistically significant (Table3). Maximum yield of grain (2816kg ha^{-1}) was noted when fertilizer was used @ 40-40kg ha^{-1} P & K and seed was planted @ 5kg ha^{-1}. Minimum yield of grains (1394kg ha^{-1}) were noted when P and K was applied @ 20-20kg ha^{-1} that was statistically equivalent where P and K was applied @ 40-40kg ha^{-1} and grain yield was recorded 1452.3kg ha^{-1} when seed was planted @ rate of 15kg ha^{-1}. These results are in accordance with finding of Rafiq *et al.*, (2010). The result showed that weight of 1000 grain and grain yield significantly differed by increasing potassium & phosphorus rate from 20-20kg ha^{-1} to 40-40kg ha^{-1}. Enhance in K_2O dose beyond 40kg ha^{-1} decreased all three parameters, most probably due to nutrients imbalance caused by excess of potassium and antagonistic effect of K+onCa^{+2}. Similar conclusion was reported by Saifullah *et al.*, (2002). This study indicated that 40kg ha^{-1} P_2O_5 was the optimal dose for maximum plant vigor and efficient nutrient uptake giving better results for thousand grain weight, number of grains head^{-1} and yield of grain while further increase in P dose affected the growth parameters of Sorghum. These results are in consistent with the findings of previous studies of many researchers (Xiang *et al.*, 2012, Mabapa *et al.*, 2010, Deliberain *et al.*, and Yasin *et al.*, 2018).

Conclusion and recommendation

It is concluded that fertilizer level of P_2O_5 40kg ha^{-1}, K_2O 40kg ha^{-1} and constant level of N @ 57kg ha^{-1} with interaction of 5kg ha^{-1} seed rate developed statistically higher grain yield of Sorghum cultivar "Sorghum 2011". Plant parameters like Plant height, number of plants m^{-2} and number of heads m^{-2} were increased with increase in seed rate from 5kg ha^{-1} and fertilizer level of PK above 40-40kg ha^{-1} but had no positive impact on grain yield. Substantially decrease in productivity is probably caused due to morphological changes resulting in taller plant with thinner stem that are more prone to lodging.

Thus it is recommended that seed rate of 5kg ha^{-1} with PK fertilizer @ 40-40kg ha^{-1} with constant level of N @ 57kg ha^{-1} must be adopted for maximum grain yield of Sorghum cultivar "Sorghum 2011". However, further investigation may be carried out to validate this conclusion by considering physiological changes in Sorghum.

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Conflict of interest statement

We declare that we have no conflict of interest.

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