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Response of Various Grain Sorghum Varieties to Nitrogen Fertilization Under Agro-Ecological Conditions of Dera Ismail Khan

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ABSTRACT

It is need of time to introduce varieties of a crop such as sorghum because there is a lack of grain and fodder for animals. A study was planned to determine how the development of sorghum would be affected by a variety of cultivars as well as various amounts of nitrogen. The experimental design was a randomized complete block, with the blocks being split up into plots along with three replications. Six cultivars such as Desi Sorghum, PARI S4, PARI S5, Sorghum 86, BR 39 and H F S were planted in the main plot. Similarly, three different nitrogen doses were planted in the sub plot (50, 100 and 150 kg/ha). A considerable impact on yield contributing traits was observed due to application of different amount of nitrogen fertilizer on above cultivars. The PARI-S4 variety that was supplemented with 150 kg ha^{-1} produced the highest documented values for panical^{-1} (2340 kg/ha), CGR (11.69 g m^2/day), grain yield (4297 kg/ha), and 1000-grain weight (27.66 g). Data revealed that variety PARI-S4 superseded remaining cultivars and nitrogen level of 150 kg/ha performed better under the conditions that were present in the Dera Ismail Khan region.

Keyword: Nitrogen, Cultivars, Yield, Sorghum

Introduction

Sorghum (Sorghum bicolor L.) is an annual C4 fodder crop that can withstand heat and drought in summer. It is ranked fifth among cereals globally (Mehmood et al., 2008). It is a versatile crop that is raised for grain, forage, and sugar, but primarily for forage. Sorghum production in Pakistan is 0.21 million tones per year, having yield of 620 kg ha^{-1} and occupying 0.34 million hectares (Anonymous, 2006). The demand for grain and forage sorghum is rapidly rising in the current environment. In May to June and from October to November, there is frequently a shortage of fodder. In Pakistan, sorghum can be grown using barani and irrigation techniques (Khan et al., 2013).

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The macro restriction in the modern world affects productivity. There are various reasons for its low yield, including improper Agro-management practices, late sowing, insufficient fertilizer, low producing cultivars, etc.

Sorghum varieties can differ in how they react to synthetic fertilizers (Kumar et al., 2010), both nutrient treatment and genetic engineering can increase the crop's production. Nitrogen is necessary for vegetative and reproductive improvement of plant and insufficient quantity causes low grain production, dry matter, and protein levels (Ashiono et al., 2005). Different nitrogenous regimes have been found to boost grain output (Cho et al., 2001; Mkhabela et al., 2001; Ma et al., 2006), and this grain yield increment might well be due to culm improvement, its height, and overall plant canopy.

There are various initiatives to introduce several sorghum hybrids that produce a lot of grain and recover the most sugar (Li et al., 2004). Adopting genotypes with high yield potential can increase the crop output in a certain area (Sarwar and Ahmad, 2003). Chemical fertilizer, particularly nitrogen are the factors that increase biological and grain yield. Similarly different cultivars have distinct growth characteristics. Hugar et al. (2010) reported that sorghum cultivars greatly varied in thousands grain weight, and grain yield while Chohan et al. (2003) explored that leaf number, leaf area and plant height have strong relationships with crop biomass. The need for sorghum cultivars to be verified and adapted to the agro-climatic conditions of Pakistan was highlighted by Chughtai et al. in 2007. The objective of the current study was to identify the genotype of grain sorghum that performs the best in Dera Ismail Khan agricultural environment by examining how different nitrogen application rates affect the response of grain sorghum cultivars.

Materials and Methods

The current study was conducted at Research Area of the Gomal University's Faculty of Agriculture in Dera Ismail Khan, (KPK) Pakistan. The split plot configuration was replicated three times as part of the RCBD design for the crop trial. In each plot, there were six rows and gap between each row was 60 cm. The distance between plants was 30 cm with the use of primary and secondary tillage tools, the field was prepared and leveled. Using a manual drill, seed was applied at a rate of 25 kg per hectare. Complete phosphorus and potassium doses were administered at60 kg/ha and 80 kg/ha respectively. These fertilizers were added throughout the sowing process, while nitrogen was applied in two dosages. When seeds were sown, the first half of the N dose was used, and the remaining split was incorporated during the first irrigation.

Detailed experimental procedure is given below;

In main plots sorghum cultivars were used like V1, V2, V3, V4, V5, V6 denote the different varieties such as Desi Sorghum, PARI S4, PARI S5, Sorghum 86, BR 39 and H F S and in sub plots different levels of nitrogen were used such as F1= 50 kg/ha, F2= 100 kg/ha and F3= 150 kg/ha.

Morphological parameters studied

Days to 50% heading were noted when 50% of the panicles on the sorghum flag leaf had appeared. Two measurements of leaf area were made at 35- and 70-days following seeding. The area of the leaves was measured by averaging the length and

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width of 5 randomly chosen plants from the treatment. This was done by multiplying the result by 0.73. Leaf area is equal to length times breadth times 0.73.

Sorghum plants that were randomly picked for height (cm) were measured, noted, and their average was collected from each sub-plot. A vernier caliper was used to measure the average stem girth (cm) of five different plants. Following oven drying of the crop samples at 35 and 70 days after planting, the crop growth rate (CGR) was deliberate by applying formula recommended for its measurement.

In each sub-plot, five sorghum panicles were chosen at random, measured for length in cm, and the average value was noted. To count the number of grains in each panicle of five chosen plants' sorghum heads, their average was calculated. With the use of a digital balance, 1,000 grains of a chosen sample from all treatments were weighed in grams. By cutting the crop in a 1 m^2 patch at maturity and letting it dry in the sun, biological yield (kg/ha) was calculated. The different parameters were obtained by adopting the following equations;

$$\mathrm{GY(kg/ha)} = \mathrm{GY(m^2)} * 10000 \quad (1)$$

$$\mathrm{BY(\%)} = \mathrm{Biomass\ (kg/ha)} * 10000 \quad (2)$$

$$\mathrm{HI\ (\%)} = \frac{\mathrm{Economic\ yield} * 100}{\mathrm{BY}} \quad (3)$$

Here in these equations “GY”, “BY” and “HI” are the grain yield, biological yield and harvest index, respectively.

Physiological parameters studied

Chlorophyll contents

Just before to the crop heading, a SPAD meter was used to measure the amount of chlorophyll. Randomly five plants were chosen randomly from each sub-plot. Yield was calculated in kg ha^{-1}.

Net photosynthesis rate

Prior to heading, the above mentioned attribute was measured. To calculate net photosynthetic rate, a sample of five randomly chosen plants was obtained. The rate of photosynthesis was measured using the CL-340 photosynthesis instrument.

Benefit cost ratio (BCR).

BCR calculations were made using the following equation:

BCR = Gross total income / Total expenditure

Statistical analysis

ANOVA technique was used to assist the statistical analysis (Steel et al., 1997), and software statistics 8.1 was afterwards used to apply the test of significance (LSD) test.

Results and Discussion

Days to 50% heading

Any crop's heading is largely influenced by its genotype and its nitrogen content. Cereals are negatively impacted by both heading before the regular duration and delayed heading. The information in Figure 1 showed how nitrogen levels were used to significantly affect the heading of various sorghum hybrids. In sorghum, nitrogen

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doses of 50 kg ha^{-1} took the longest (71.44) days to head, while nitrogen dose 150 kg ha-1 took the shortest i.e. 58.61 days. This may be because the sorghum was fertilized with the highest nitrogen dose and had early heading due to soil variance. Days to heading varied greatly amongst sorghum cultivars as well. Sorghum-86 produced heads (58.77 days earlier) than all other kinds under study. The PARI-S4 variety produced heads the earliest (73.00 days after sowing), followed by the PARI-S5 variety (70.44 days). Some other reports showed that nitrogen dosage greatly influenced emergence of sorghum head; support our conclusions (Buah 2009 and Moghaddam et al. 2007).

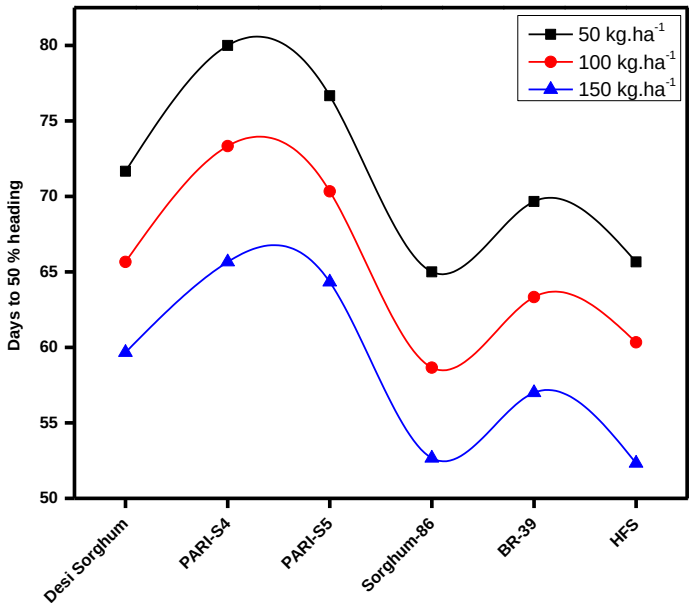

Figure 1. Different levels of nitrogen and various cultivars impact the time it takes for sorghum to reach 50% heading.

Leaf area at 35 days after sowing

Role of leaves in a plant's photosynthesis process is widely recognized. The data showing an increase in leaf area may be able to foretell the buildup of photosynthetic material for future plant development. Figure 2 showed significant differences in sorghum cultivars and nitrogen treatments. The largest leaf area (833.78 cm2) was measured for PARI-S4, and the smallest (735.22 cm2) for HSF cultivar. However, Sorghum-86 had the smallest leaf area ever recorded (525.0 cm2). Different nitrogen concentrations played a significant role in increasing leaf area. In treatments 150 kg ha-1 nitrogen, the largest leaf area (775.33 cm2) was measured. The lowest leaf area (478.56 cm2) was measured where nitrogenous fertilizer was used @ 50 kg ha-1. This was due to accelerated cell multiplication and elongation caused by nitrogen administration, which led to the induction of maximum leaf area (Stals and Inze, 2001). Pholsen et al. (2001), who explained that leaf area of sorghum varieties can fluctuate with varying levels of nitrogen, supported our findings.

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Leaf area 70 days after sowing

The collection and distribution of photosynthetic material into the crop's economic portion is considered to be the role of the leaf, although its contribution to the final biomass of the crop is also recognized. Data on leaf area (cm2) at 70-DAS revealed a strong relationship between nitrogen dosages and variety (Figure 2). Different cultivars' leaf area was greatly impacted as well. PARI-S4 reported the largest leaf area (1833.6 cm2), followed by PARI-S5 with 1607.7 cm2. Cultivar BR-39 had the smallest leaf area (1018.0 cm2) ever observed. Maximum leaf area expansion resulted after nitrogen delivery (150 kg ha-1). In comparison to a lower dose of nitrogen, which resulted in a leaf area of 1073.9 cm2, the highest dose produced a leaf area of 1631.8 cm2. However, when Sorghum varieties were paired with nitrogen fertilizer doses, significant results were observed. Maximum leaf area of 2064.06 cm2 and 2016.7 cm2 were obtained when PARI-S4 and PARI-S5 were combined with a nitrogen dose of 150 kg ha-1, respectively. Leaf area of 1959.3 cm2 was obtained when PARI-S4 was combined with a dose of 100 kg. BR-39 had a minimum leaf area of 831.3 cm2 when nitrogen fertilizer was administered at a rate of 50 kg/ha. Our results were supported by the work of Khalid et al. (2010) and Akram et al. (2010), where they discovered that nitrogen administration led to sequential increases in leaf area.

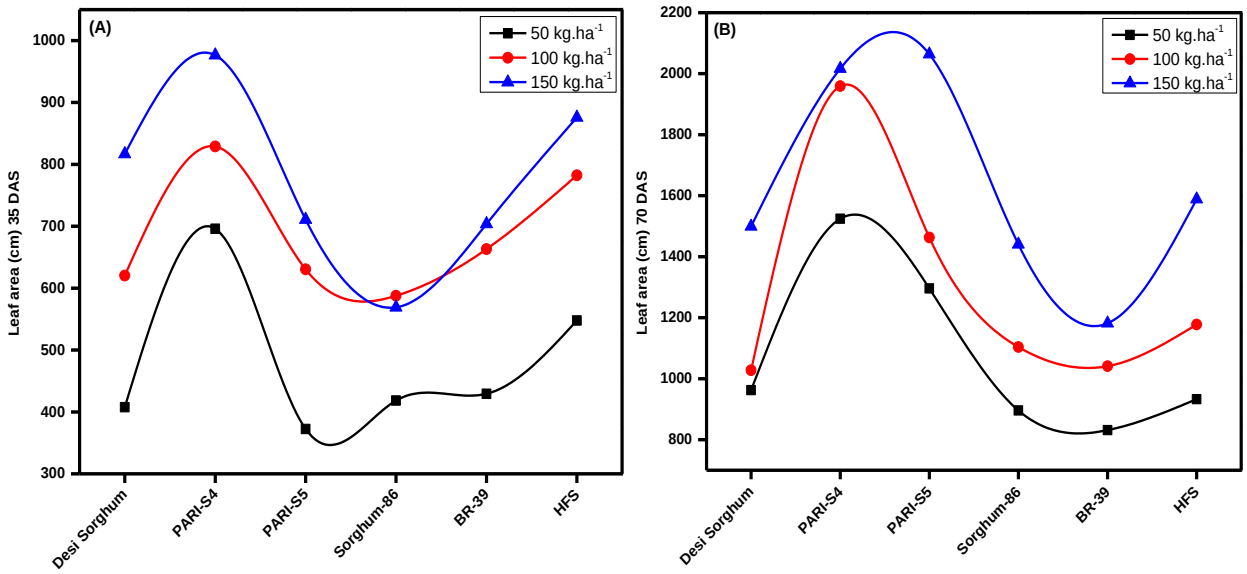

Figure 2. Varying levels of nitrogen and different cultivars affect the leaf area of sorghum plants at (A) 35 days and (B) 70 days after sowing.

Plant height

It is a genetically determined metric that can be affected by the soil's fertility, the amount of moisture in the air, the number of plants present, and the environmental challenges that the crop must contend with throughout its growth cycle. Data on plant height (Figure 3) showed statistically significant variations when nitrogen levels and several sorghum cultivars were used. HFS had tallest plants (317.48 cm), followed by

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BR-39 with 281.92 cm, and PARI-S4 with the smallest (223.30 cm). The nitrogen doses significantly improved the sorghum plants' height as well. It gradually rose as the nitrogen dose was raised. Wherever the maximum nitrogen dose (150 kg ha-1) was applied, the tallest plants (290.90 cm) were measured. In the plots that received the least quantity of nitrogen treatment, the dwarf plants (232.51 cm) were found (50 kg ha-1). The combination between nitrogen and variety also produced noteworthy results. The largest plants (347.90 cm) were seen with a single treatment of 150 kg N ha-1 and the variety HFS. Shortest plants were produced by the variety PARI-S4 with 50 kg N ha-1 (184.26 cm). Miko and Manga (2008) observed good results of nitrogenous fertiliser for sorghum hybrids, which supports their findings. The genetic attribute of the variety used in the experiment and the usable nitrogen level among the nitrogen regimes used in the treatments were the causes of the elevated heights in HFS.

Stem girth

The crop's stem determines its resilience to harsh weather conditions. Figure 3 indicated that different dose of nitrogen and variety had a substantial impact on stem girth. PARI-S4 had the largest stem girth (6.16 cm), which was followed by PARI-S5 (5.28 cm). In the HFS variety, the thinnest stem (3.97 cm) was measured. The girth of the sorghum stem was also considerably impacted by nitrogen levels. The thickest stem girth (5.47 cm) was produced at the highest nitrogen rate (150 kg ha-1), whilst the weakest stems were produced at the lowest nitrogen rate (50 kg ha-1) (4.54 cm). According to Samia et al. (2010) and Khalid et al. (2010), nitrogen fertilization significantly influenced stem thickness. The relationship between nitrogen content and sorghum variety, however, turned out to be insignificant. The interactive mechanism of 150 kg N ha-1 and cultivar PARI S-4 generated the largest stem girth (6.76 cm), and the combination of 50 kg N ha-1 and HSF cultivar produced the smallest stem girth (3.60 cm).

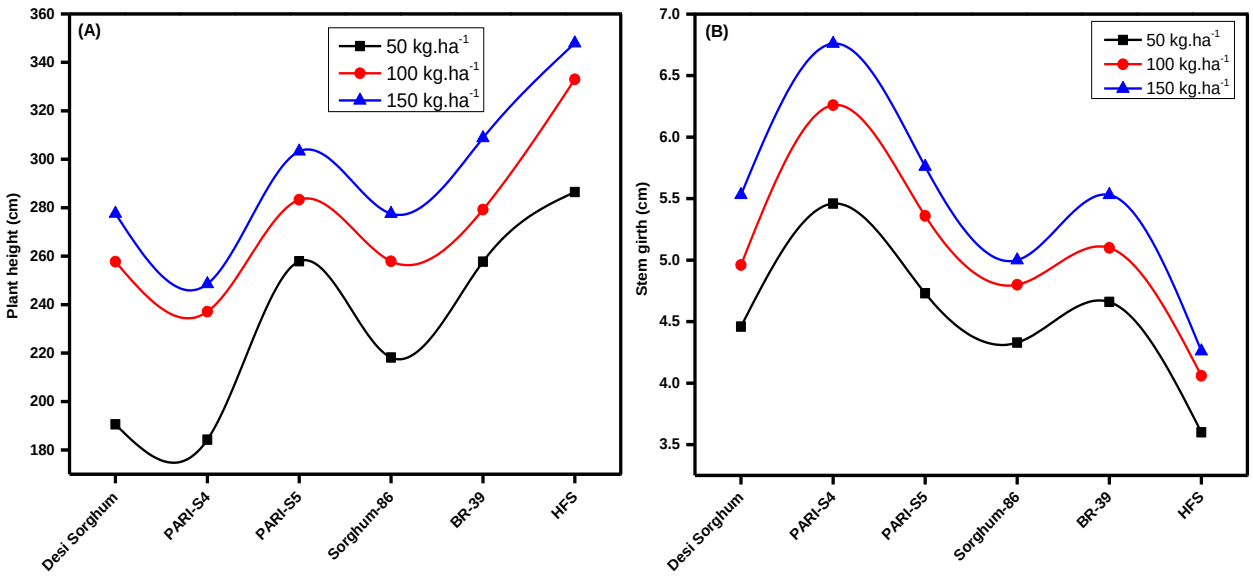

Figure 3. Different levels of nitrogen and various cultivars impact the (A) height and

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Online ISSN 3007-3197
Print ISSN 3007-3189

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(B) stem girth of sorghum plants.

Crop growth rate

When managed appropriately, crop growth rate which governs how much weight a crop gains during development can boost crop yield. Data from Figure 4 showed that utilizing different nitrogen doses and types resulted in substantial changes in CGR. PARI- S4 showed maximum growth rate (10.71 g m^{-2}/day), followed by H F S. (8.12 g m^{-2}/day). BR-39 had the lowermost crop growth rate (3.42 g m^{-2}/day). The rate of crop growth was greatly impacted by various nitrogen levels as well. Maximum nitrogen use (150 kg ha-1) produced the highest crop growth rate (7.02 g m^{-2}/day), whereas the lowest dose (50 kg/ha) showed in the lowest crop growth rate (5.57 g m^{-2}/day) in sorghum. The combination between nitrogen rates and cultivars also pointed to a substantial result. The PARI-S4 crop, which was given N at a rate of 150 kg ha-1, experienced the highest crop growth rate (11.69 g m^{-2}/day). BR-39 variety had the lowest crop growth rate (2.87 g m^{-2}/day) with 50 kg N ha-1. The rise in sorghum's dry weight caused by nitrogen fertilizer was proven by Olubemi and Ababyomi in 2016.

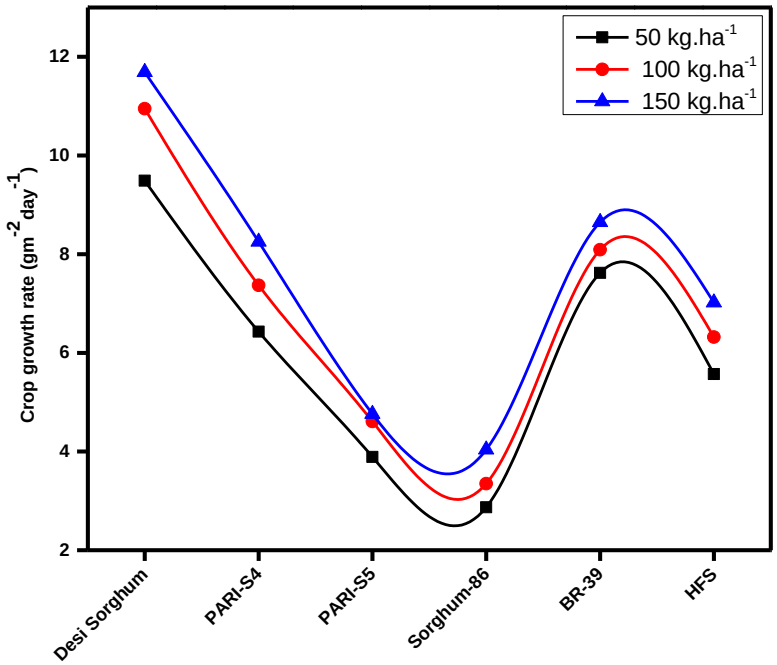

Figure 4. Varying levels of nitrogen and different cultivars affect the crop growth rate of sorghum.

Panicle length

Utilizing various nitrogen doses caused a considerable difference in the panicle length of the sorghum plant. The panicle's maximum length, where 150 kg of nitrogen per hectare was treated, was measured at 25.60 cm (Figure 5). Treatments using nitrogen at a rate of 50 kg/ha were given modest panicle lengths (19.51 cm). The variations also produced results that were significant (p 0.05). The HSF cultivar of sorghum had the longest maximal panicle, measuring 32.33 cm, and genotype PARI-S4, measuring

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28.84 cm, came in second. Sorghum-86 cultivar's small-sized panicle (14.82 cm) was measured. The relationship between nitrogen dosages and variety also had a major impact on panicle length. The combination of the HSF cultivar with 150 kg N/ha resulted in the longest panicles (35.00 cm), which were followed by (33.00 cm) when using 00 kg N/ha for HSF. Then came 31.80 cm in PARI-S4, 150 kg N/ha in close succession. The Sorghum-86 x 50 kg N/ha combination produced the smallest panicles, measuring 11.60 cm. Hassan and Bibinu (2010) as well as Miko and Manga (2008) applied the largest amount of nitrogen in sorghum and reported maximal panicle length, support these findings.

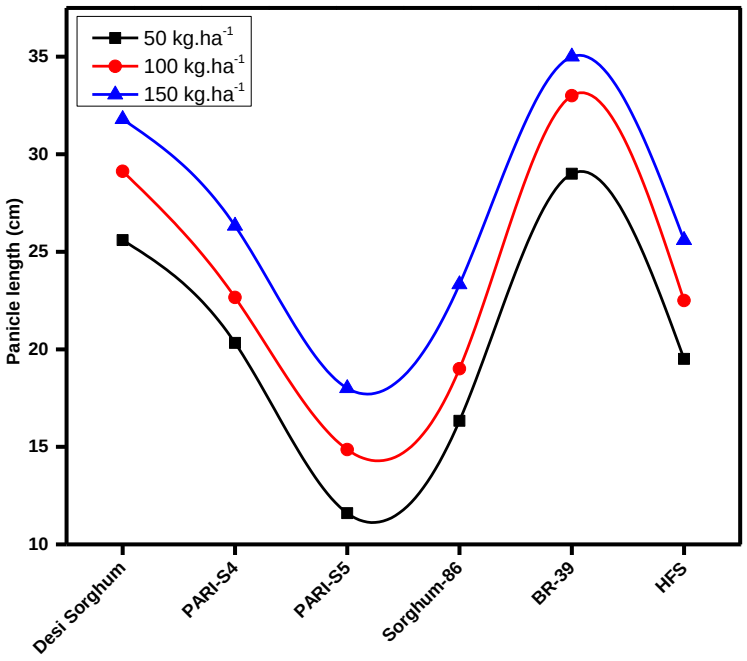

Figure 5. Different levels of nitrogen and variations in cultivars impact the length of panicles in sorghum plants.

Chlorophyll content

Chlorophyll and nitrogen are closely related, which is reasonable given that nitrogen is a key component of structure of chlorophyll, chloroplast development, and accumulation of chlorophyll (Daughtry et al., 2000 and Tucker, 2004). Figure (6) indicated that applying various N levels to various sorghum cultivars had a substantial impact on chlorophyll concentration. 50 kg N/ha had the lowest chlorophyll content (38.33), whereas nitrogen dosages of 150 kg N/ha had the highest chlorophyll content (41.31). The largest nitrogen dose, which is necessary for plants to synthesize chlorophyll, may be the cause of this. The amount of chlorophyll varied greatly between sorghum cultivars as well. Variety HFS displayed the greatest chlorophyll (43.11) while BR-39 displayed the lowest (35.17). Mehasen and Al-Fageh (2004)'s findings that variety & nitrogen affect chlorophyll contents corroborate our findings.

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http://amresearchreview.com/index.php/Journal/about

Net Photosynthesis rate

In reality, photosynthesis in plants is the process by which the complete amount of light energy is transformed into chemical energy. Information on NPR (Figure 6) revealed a large variation in types. Maximum NPR (62.59 mole/m^2/sec) was recorded in PARI-S5, trailed by 62.27 mole/m^2/sec value in PARI-S4, while the lowest was displayed by BR-39 (41.44 mole/m^2/sec). Data show that with each successive increase in nitrogen dose, net photosynthesis rate rose. The maximum nitrogen dose (150 kg N/ha) was associated with the highest NPR value (62.39 mole/m^2/sec), whereas the lowest nitrogen dose (47.29 mole/m^2/sec) was associated with the highest NPR value. Varieties and nitrogen continue to interact in a crucial way. The maximum net photosynthetic rate (75.84 mole/m^2/sec) was measured using 150 kg N/ha and PARI S-5. Then came PARI-S4 with 150 kg N/ha (70.77 mole/m^2/sec) after it. However, the mixture of BR-39 and 100 kg N/ha produced the lowest net photosynthetic rate (40.08 mole/m^2/sec). The lowest stomatal resistance, which led to an increase in transpiration and nutrient flow through xylem vessels, may be associated with the highest net photosynthetic rate. These results are supported by Zhao et al. (2005) and Mousavia et al. (2012) who found that adding more nitrogen to sorghum increased its net photosynthetic rate.

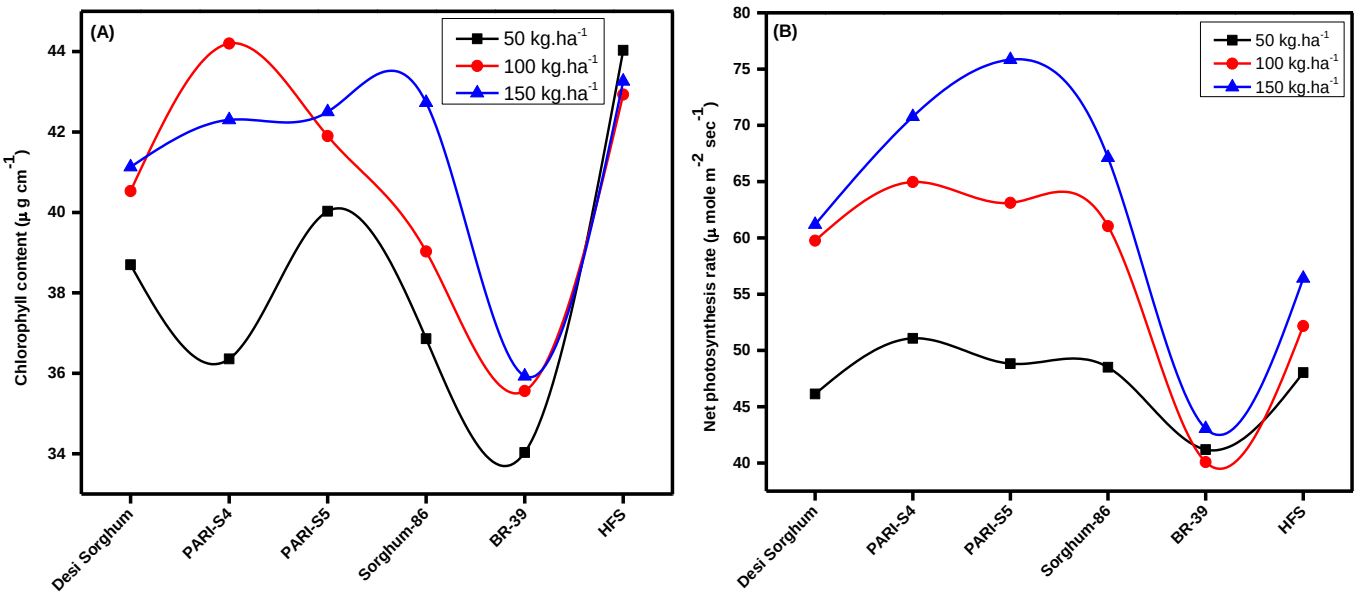

Figure 6. Impact of different nitrogen levels and cultivars on the (A) chlorophyll content and (B) net photosynthesis rate in sorghum.

Number of grains (panicle^{-1})

The number of grains and the 1000-grain weight are strongly correlated with grain yield (Ma et al. 2006; Buah and Mwinkara, 2009). The information in Figure 7 indicated significant results for the N levels, sorghum varieties, and their interactions. The sorghum cultivar BR 39 responded with the fewest grains (921 panical^{-1}) while variety PARI-S4 produced the most grains (2212 panical^{-1}). Additionally, nitrogen levels exhibited considerable behavior, with the greatest nitrogen dose producing the

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Print ISSN 3007-3189

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most grains (1472 spike^{-1}) (150 kg ha^{-1}). The lowest number of grains in the sorghum head was 1232 where 50 kg ha^{-1} of nitrogen was broadcasted. According to Mousavia et al. (2012), 150 kg N ha-1 contributed to an increase in grain production. These findings concur with those of Mutava et al. (2011), who analyzed considerable variances across several sorghum cultivars. Significant impacts were also produced when sorghum genotypes and nitrogen regime were combined. PARI-S4 interaction with 150 kg N ha^{-1} formed the most grains (2340), followed by PARI-S4 and 100 kg ha-1 and PARI-S4 and 50 kg ha^{-1}. The Desi Sorghum and 50 kg N ha^{-1} combination produced the fewest grains per spike (900).

1000-grain weight

A key yield component linked to yield is thousand grain weights. The data in Figure 7 demonstrated a substantial variation in 1000-grain weight when utilizing different doses of nitrogen and cultivars of sorghum. The highest grain weight of 1000 grains (23.55 g) was demonstrated by BR-39, which was statistically comparable to Desi sorghum (23.44 g) and PARI-S4 (23.11g). In H F S, the smallest seed weight (15.88 g) was noted. The highest nitrogen dose (150 kg ha^{-1}) generated the large grains (24.88 g), whereas the lowest nitrogen dose resulted in the smallest grain weight (19.22 g). Variety and nitrogen interaction was also proven to be important. PARI-S4 with 150 kg N ha^{-1} demonstrated maximum (27.66 g) thousand grain weights. This might be because the variety receiving the right quantity of nitrogen has accumulated enough sink. The interaction of BR-39 with 150 kg of nitrogen per hour came next (27.33 g). The combination of variety HSF and 50 kg N ha^{-1} produced grains with the lightest weight (13.00 g). Our results are very similar to what Almodares et al. (2006), Wani et al. (2004), and Sami et al. (2006) concluded (2014).

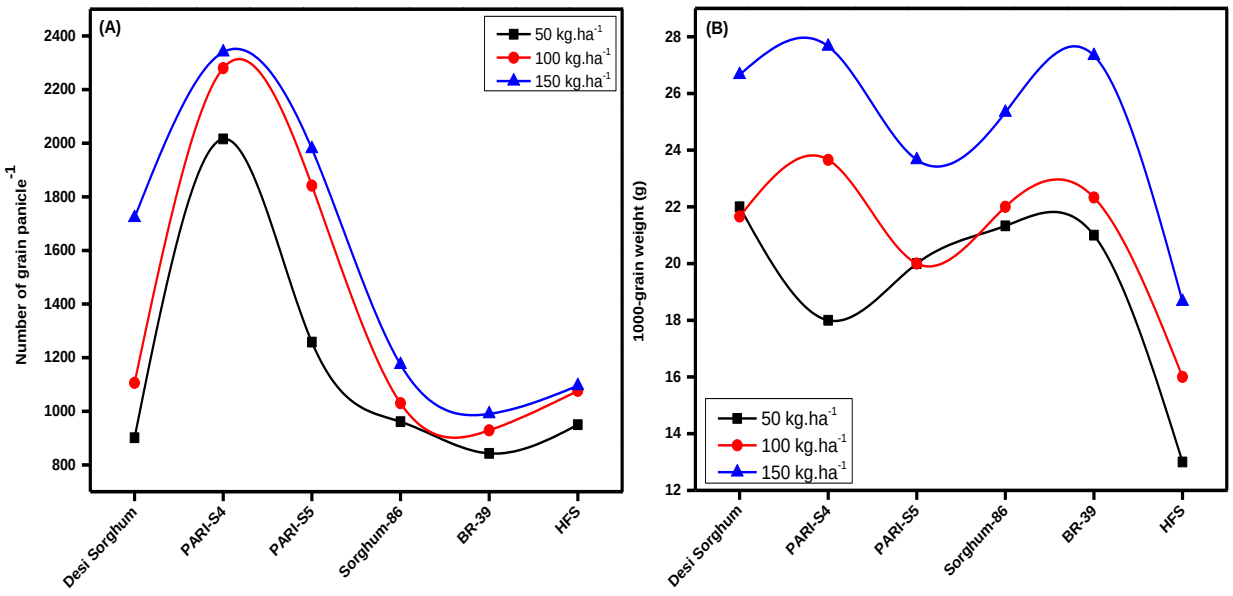

Figure 7. Influence of different nitrogen levels and cultivars on the number of (A) grain per panicle and (B) weight of 1000 grains in sorghum.

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Biological yield

Sorghum biomass yield showed significant values for varieties and nitrogen concentrations (Figure 8). the highest amount of biomass (14168 kg ha^{-1}) was obtained from treatments supplied with 150 kg N ha-1. The use of the lowest N-dose resulted in the observation of the lowest biomass (12233 kg ha^{-1}). According to research by Ayub et al. (2002), more nitrogen was used to achieve the highest biomass. Greater vegetative growth may be the cause of the increased biomass. The biological yield varied greatly between the types as well. Out of all the cultivars, PARI-S4 produced the most biomass (16591 kg ha^{-1}). H F S and BR-39 both had the lowest biomass yields (10644 and 10672 kg ha-1, respectively). The relationship between nitrogen content and variety remained important. In PARI-S4 with 150 kg N ha^{-1}, the maximum biological yield (17253 kg ha^{-1}) was measured. In PARI-S4with 100 kg and 50 kg ha^{-1}, the biological yield (16560 and 15960 kg ha^{-1}) was observed respectively, behind this trend. The lowest yield of biomass (9167 kg ha^{-1}) was produced by the interaction of variety HSF and 50 kg N ha^{-1}.

Grain yield

Figure 8 showed that the yield of wheat was considerably influenced by the nitrogen dose and different sorghum genotypes. Maximum grain yield was produced by cultivar PARI-S4 (3729 kg ha^{-1}), then PARI-S5 (variety) (3195 kg ha^{-1}). HFS noted the lowest grain yield (1394 kg ha^{-1}). Highest economic yield (2686 kg ha^{-1}) was obtained in nitrogen plots supplied with 150 kg ha^{-1}, while a nitrogen dose of just 50 kg ha^{-1} yielded 2081 kg ha^{-1} of wheat grain yield. Nitrogen and different types worked together to generate an important result. Maximum grain yield (4298 kg ha^{-1}) was produced by the interaction of 150 kg N ha^{-1} with PARI-S4; it was followed by grain yield 3786 kg ha^{-1} obtained from 100 kg N ha^{-1} along with PARI-S4. The genetic potential of the variety and the ideal nitrogen dose may be the reasoning behind maximum grain output, which ultimately increased grain yield. Combining H F S with 50 kg N ha^{-1} resulted in the lowest grain yield of 1099 kg ha^{-1}. Ashiono et al. (2005) and Rashid et al. (2007), who achieved maximum yield by applying the largest amount of nitrogen, support our findings. The more grains per panicle, the plumpness of the grains, and strong dry matter production during the grain filling stage could also contribute to the greater grain yields.

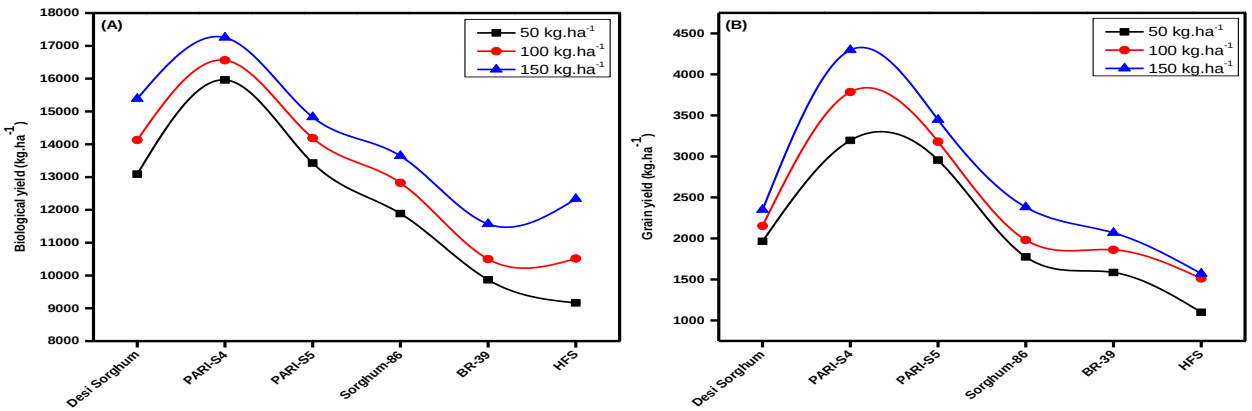

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Figure 8. The impact of different nitrogen levels and cultivars on the (A) biological yield and (B) grain yield in sorghum.

Harvest Index (%)

The usual ratio of grain to biomass output expressed in percentage is known as the harvesting index. Results shown in Figure 9 showed effects for harvest index (%) that were statistically significant. The harvest index was greatly altered by different cultivars. In the varieties PARI-S4 and PARI-S5, the maximum harvest index was determined as being (22.54%) and (22.41%), respectively. In HFS, the lowest harvest index (13.00%) was determined. The harvest index also showed statistically significant results with nitrogen application. 150 kg N ha^{-1} produced the highest harvest index, which was 18.58%. 50 kg N ha^{-1} produced the lowest harvest index i.e. 16.57%. Our findings were also supported by Mahmood et al. (2001) and Bakht et al. (2007), who explained the strong impact of nitrogen on the index of cereal harvest. Significant insights were also revealed by the interaction. Maximum index (24.93%) was obtained in PARI-S4 by combining 50 kg N ha^{-1} and 150 kg N ha^{-1} tracked by PARI-S5, which resulted in a 23.23% harvesting index. The minimum value of harvest index (11.96%) was calculated for interaction between HSF and 50 kg N ha^{-1}.

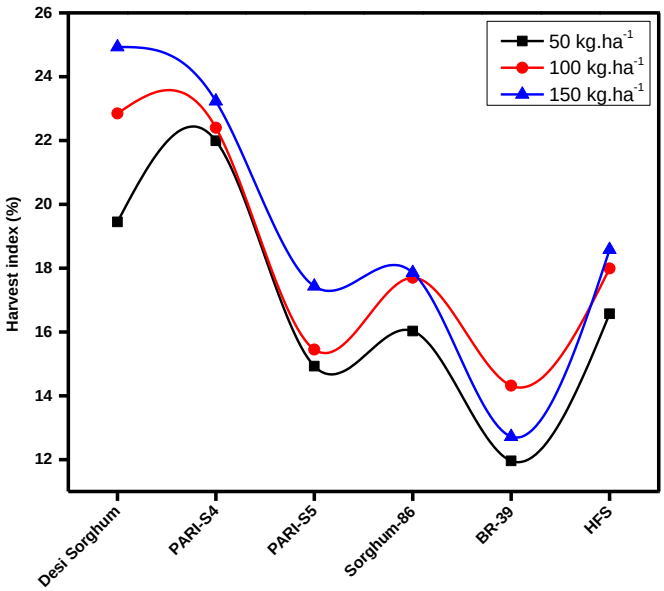

Figure 9. Investigation of the influence of different nitrogen levels and cultivars on the harvest index (%) in sorghum.

Benefit cost ratio (BCR)

To know the financial benefit or loss of the farmer without calculating its benefit cost ratio is quite a difficult task. The information in Table 10 showed varied benefit-cost ratios that were achieved when various cultivars and nitrogen doses were combined. The PARI-S4 combination with 150 kg N ha-1 received the highest BCR (2.62) and net income (Rs. 90,513/-). The interaction between PARI-S4 and 100 kg N ha-1, with a benefit-cost ratio of 2.50 and a net return of Rs. 79887/-, followed this trend.

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However, treatments receiving 50 kg of nitrogen per hectare per annum in addition to variety HSF had the lowest BCR (1.04), and the lowest net income (1936 rupees) were recorded.

Conclusion

Sorghum not only provides grain but also fodder, will only be the ultimate alternative in the current situation given the low market prices of key crops and the lack of rainfall. The findings of this study showed that newly produced sorghum cultivars perform best when a significant nitrogen dose is applied. In particular, sorghum variety PARI-S4 behaved remarkably well, and the best nitrogen application density employed in the experiment was 150 kg ha-1. Additionally, this combination yielded the highest benefit cost ratio (2.62) and net return of 90513 rupees.

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