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Influence of Different Fertilizers and Water Stress on Sorghum Yield and its Components

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Abstract- Sorghum is a vital forage crop in the cereal family, known for its resilience in dry conditions and high water use efficiency, leading to desirable yields even under drought stress. In order to further understand the dynamics of grain sorghum production, this study was conducted over two agricultural years (2019 and 2020) in Khorramabad. The experiment utilized a split-plot factorial design with four replications, employing a randomized complete block design. The study investigated the impact of drought stress and fertilization management on grain sorghum production. Drought stress was imposed by cutting off irrigation at three levels, including normal irrigation and irrigation at the vegetative and reproductive stages. The secondary factor involved a factorial design incorporating three levels of organic fertilizer, namely vermicompost, chemical fertilizer based on soil test, and combined use of vermicompost and chemical fertilizer. Two cultivars of Sepideh and Kimia were used in subplots. Data collected included yield per hectare, plant height, stem diameter, and number of days to maturity. A combined analysis of variance was initially performed to analyze the impact of stress, cultivar, and fertilizer on the quantitative, qualitative, and phenological indices of grain sorghum. Due to non-significant effects of year and year interaction in different factors, the analysis was based on the mean of two years. The results demonstrated significant effects of stress, cultivar by stress interaction, and fertilization on the measured traits. Particularly limited irrigation during the reproductive stage, stress had a negative influence on the crop's quality and yield. Conversely, the application of vermicompost fertilizer significantly improved the studied traits. Additionally, the Sepideh cultivar outperformed the Kimia cultivar in all parameters except protein ratio. Under imitated irrigation during the vegetative stage, the yield of Sepideh cultivar was 8 tons per hectare, while Kimia cultivar yield was 4.36 tons per hectare. Similarly, under drought stress during the reproductive stage, the yield of Sepideh cultivar was 7.67 tons per hectare, and Kimia cultivar yield was 4.54 tons per hectare. Overall, this research highlights the importance of effective crop management practices for moderating the adverse effects of stress on grain sorghum production.

Keywords- Grain sorghum, Irrigation cutoff stress, Vermicompost, Sepideh cultivar, Kimia cultivar

Introduction

Sorghum bicolor is a crucial forage crop in the grain family due to its ability to tolerate drought and its high efficiency in water utilization, leading to satisfactory yields under dry conditions (Rafiei, 2014). Native sorghum populations have been cultivated in central, eastern, and southeastern regions of Iran since ancient times. These plants were introduced to the country through the Silk Road. In recent years, there has been a significant increase in the area under cultivation of this plant in Iran. In 2000, the area dedicated to sorghum cultivation reached over 40,000 hectares, with 30,000 hectares specifically allotted for forage sorghum. The yield of forage sorghum ranged from 2 to 4 tons per acre concerning water availability and 6 to 10 tons per hectare in terms of grain sorghum production (Earl and Davis, 2003). With its exceptional performance and adaptability to harsh environmental conditions, sorghum farming remains one of the primary agricultural activities in Iran's arid and semi-arid regions.

The ability of plants to respond to drought stress depends on the nature of water deficiency and can be classified into short-term, medium-term, and long-term responses. Short-term response involves a reduction in maximum CO_2 uptake. Medium-term responses include osmotic regulation through the accumulation of organic salts, while long-term responses involve complex genetic patterns of the population (Pessark, 2009). The impact of prolonged drought on physiological and morphological processes significantly affects yield and is influenced by various factors. The response of plants to drought stress is influenced not only by the timing of the stress in relation to the plant's life cycle and water availability in the root zone but also by inherent plant properties. Plants employ various mechanisms, including stomatal closure, cuticle thickening, reduction in transpiration surface, increased root weight and length, prevention of protein loss, maintenance of photosynthesis, and osmotic regulation, to resist drought stress (Pandey et al., 2000). Sorghum is particularly susceptible to water stress, with various plant mechanisms affected during its growth period, such as the leaf surface index (Rafiei, 2014). However, adequate nitrogen treatment can enhance sorghum growth and yields, with fertilizer and yield components significantly impacting the crop (Turget, 2010). Sorghum is a widely cultivated crop that exhibits a positive response to fertilizers, especially nitrogen, under well-irrigated conditions. However, the extent of this response is influenced by the intrinsic fertility of the soil and other environmental factors that may act as limiting factors. The optimal economic dosage of nitrogen can vary between zero and 180 kilograms per hectare, depending on the prevailing environmental conditions. Nitrogen plays a crucial role in enhancing yield by stimulating amino acids and growth hormones. Plants assimilate nitrogen in the form of nitrates (NO3), ammonium ions ($NH4^+$), and urea (NH2) (CO_2). Nitrates are the predominant form of nitrogen in soils, while NH3, NH4, and urea quickly convert into nitrates. This conversion frees up +H and reduces soil pH (Mohamadkhani, 2014). Compost is an organic fertilizer resulting from the microbial decomposition of animal and plant residues. This biological fertilizer is recognized as a valuable source of nutrients for crops (Darzi et al., 2011). Vermicompost is a peat-like organic material with beneficial effects on soil structure, ventilation, moisture absorption, and water-holding capacity. The organic carbon present in vermicompost gradually releases nutrients into the plant root system, thereby optimizing their uptake process. Vermicompost is rich in useful micronutrients that enhance plant performance. These nutrients become readily available to plants upon exposure to soil microorganisms (Mohamadkhani, 2014). Therefore, this study aims to investigate the response of two grain sorghum varieties to different factors such as drought stress, chemical fertilizers, and vermicompost in the Khorramabad region while examining their performance and characteristics.

Materials and methods

This investigation was conducted over the 2019 and 2020 agricultural seasons in the temperate region of Khorramabad, situated at 48 degrees and 19 minutes east longitude and 33 degrees and 29 minutes north latitude. The experiment utilized a split-plot factorial design with a randomized complete block design comprising four replications. Water stress was induced by interrupting irrigation at three levels: normal irrigation, interruption of irrigation during vegetative and reproductive stages as main plots. Interruption of irrigation during the vegetative stage was implemented from the fourth leaf stage until the panicle initiation stage, whereas interruption of irrigation during the reproductive stage was carried out from the flowering stage until the end of flowering. The biological fertilizer treatments in this study included the application of chemical fertilizer based on soil analysis, vermicompost biological fertilizer at a rate of 6 tons per hectare, and a mixed fertilizer consisting of 3 tons per hectare of vermicompost biological fertilizer and half of the recommended chemical fertilizer. Two sorghum varieties, namely Sepideh and Kimia, were tested in the sub-plots. The factorial combinations of variety and fertilizer applications were evaluated. The selection of these two varieties was based on their adaptation to the climatic conditions of Khorramabad and their popularity among local farmers. Each plot comprised of four rows, each six meters in length, spaced 60 cm apart, and with a plant density of 200,000 plants per hectare. The replications were separated by three meters, while the main plots were separated by three meters with sub-plots spaced one meter apart. Simultaneous planting was carried out in early July. Observations were made during the growth season and at the flowering stage, including measuring the maximum height of the plant, surface area, and height of each leaf from the ground surface to determine the distribution of leaf area index (LAI). Biological yield was measured at harvest. Data analysis was performed using SAS version 9.2, which included normality tests and variance analysis using the GLM method. Mean comparisons were done using LSD, while boxplots were used to examine the relationship between traits and treatments. R software was utilized for drawing boxplots and analyzing relationships between variables.

Results and discussion

All the studied traits were analyzed over two consecutive years using a split-plot design with replication and year considered randomly, while other independent factors remained fixed. The mixed command in SAS software was applied to analyze the complex design (Table 2). However, as the year effects and year interaction with other sources of variation were insignificant, the data from both years were averaged and analyzed based on the two-year average for all traits (Table 3). The analysis of mean data across environments when the treatment interaction effect is not significant has been proposed by Malosetti et al. (2013). The variance analysis results on the two-year mean data based on the split-plot factorial experiment of different traits revealed that, except for plant height ($p<0.01$) and days to flowering ($p<0.01$), other traits were significant without triple interaction effects (stress in variety under fertilizer). The fertilizer interaction effect on stress had no significant impact on other traits, except on plant height ($P<0.01$) and forage yield ($P<0.05$). For grain weight and leaf area index traits, the only significant effect was observed for stress ($p<0.01$). The number of plants per unit area trait was significantly affected by variety alone ($P<0.01$). The variety-fertilizer interaction effect significantly impacted flowering time, maturity time, height, protein percentage, chlorophyll index, cluster length, yield, and forage yield traits. On the other hand, the variety-stress interaction effect had a significant effect on all traits, except for leaf area index, the number of plants per unit area, and grain weight (Table 3).

Based on the results of variance analysis and mean values comparison, the interaction effect of fertilizer stress did not have a significant impact percentage-wise on the recorded traits. The majority of variations were attributed to the interaction effects of stress in variety and fertilizer in variety for different traits. Graphs 1 and 2 depicted the interaction effect of fertilizer stress on various traits via mean comparisons.

The results revealed that phonological traits, such as days to maturity and days to flowering, are mostly influenced by the variety, though stress during developmental stages prolonged plant flowering and maturation. Rafiei (2014) suggested that increasing water stress during the developmental phase of sorghum halts inflorescence development; after re-irrigation, inflorescence resumes its development, taking more time for the developmental stage and plant growth. In several studies, the genotype has been found to significantly affect flowering and maturation time. Pabendon et al. (2012) reported that flowering time in sorghum varies between 50 to 90 days. Examining the fertilizer interaction effect in variety for days to flowering and days to maturity traits revealed that the Kimia variety flowered earlier than the Sepideh variety. Additionally, vermicompost fertilizer usage resulted in better performance for early maturity compared to the other two fertilization treatments. Reports indicate significant growth improvement of sorghum concerning plant height and leaf number due to soil organic matter modification. The growth of agricultural products increased due to improved soil quality after treatment with modified organic materials (Steven, 2012; Pabendon et al., 2012).

Treatment with vermicompost fertilizer slightly delays the day of greening, possibly due to the delayed availability of organic matter required for growth. Therefore, the day of greening occurs somewhat slowly, but the effect of vermicompost fertilizer during the growth period indicates an increase in plant growth rate and a decrease in days to the end of flowering and maturity date. The Sepideh variety outperformed in all economic traits and showed a faster and more complete growth period. Moreover, vermicompost fertilizer retains more water in the soil, which seems to accelerate plant growth by making more water available, consistent with Shamsi Mahmodabadi et al. (2012).

The performance of seed, biological, and forage yields of sorghum is affected by the interaction of cultivar with fertilizer and cultivar with stress. The highest values for these traits belonged to the Sepideh cultivar, whereas the lowest belonged to the Kimia cultivar. The Sepideh cultivar had similar seed yield in all three fertilizer treatments (Figure 2). While the biological performance of the Sepideh cultivar was comparable under vermicompost and NPK fertilizer use conditions, the forage yield of both Sepideh and Kimia cultivars was highest in the vermicompost treatment compared to other fertilizer treatments. It seems that vermicompost provides suitable conditions for these two cultivars as it has a high capacity for water absorption and retention of nutrients, resulting in high porosity, adequate ventilation, and drainage. The use of vermicompost in sustainable agriculture not only increases the population and activity of beneficial microorganisms in the soil, such as mycorrhizal fungi and bacteria in the rhizosphere, but also provides necessary plant nutrients, including nitrogen, phosphorus, and soluble potassium, resulting in improved growth and performance of crop plants (Arancon et al., 2004). In a study entitled "Determination of the Best Vermicompost Treatment on Sepideh Sorghum," the highest dry and wet forage yield was obtained through applying 8.64 and 3.5 tons of vermicompost per hectare, respectively, with no significant difference observed with the treatment of 150 kg nitrogen per hectare, consistent with the results of this study (Kazemi, 2000).

In another study by Shuaibu et al. (2018), it was observed that the application of compost derived from 2 tons of poultry manure per hectare resulted in the highest sorghum yield compared to other fertilizers. This may be attributed to the carbon-to-nitrogen ratio of poultry manure fertilizer and its impact on the soil, leading to early release of plant nutrients into the soil. This study is consistent with the aforementioned report and has suggested that vermicompost not only increases product growth but also enhances nitrogen consumption efficiency.

Vermicompost creates soil porosity, which can enhance root penetration and maximum uptake of mineral and organic materials, making it a recommended fertilizer for farmers in the region (Rafiei, 2014). Additionally, vermicompost contains nitrogen, as well as other macro and micronutrients, which can promote vegetative growth and greater nutrient uptake.

Water stress significantly and negatively impacted the performance and yield components of sorghum plants, with the highest yield and yield components observed in the treatment without stress. Stress during the growth stage led to reductions in traits such as biological performance, forage yield, and height, with the greatest decline occurring during the cutting phase in the vegetative period. Furthermore, stress during the growth stage caused a decrease in seed yield, protein percentage, leaf surface index, and chlorophyll index.

Stress creates a crisis in the plant, ultimately disrupting its growth cycle and leading to reduced performance, consistent with results reported in corn plants (Alizadeh et al., 2008). Fertilizer had a significant effect on traits such as biological performance, forage yield, and dry matter content. The vermicompost treatment showed the highest average forage yield, while the chemical fertilizer and vermicompost treatments had the highest biological performance, indicating the positive impact of vermicompost. The lowest numerical values for these traits were observed in the combined fertilizer treatment. Cultivar also significantly influenced performance and yield components, with the Sepideh cultivar treatment exhibiting the highest values for biological performance, forage yield, seed yield, and height. The findings suggest that biological and forage performance traits were more susceptible to the interaction of stress and cultivar, with the highest values observed in the treatment without stress and the Sepideh cultivar, indicating the negative effect of stress on performance and yield components. On the other hand, lower values of biological performance and forage yield associated with stress during the growth stage and the Kimia cultivar, coupled with lower seed yield values in the stress treatment during the growth stage and the Kimia cultivar, indicate that the Kimia cultivar is sensitive to stress conditions in the region. These findings are consistent with Dehghan Harati et al.'s (2009) observations, who acknowledged that "the Kimia cultivar was not identified as a stress-tolerant cultivar." Performance is influenced by various factors that can be explained using multivariate methods. However, the positive effect of vermicompost on performance and yield components may be attributed to the presence of micro-nutrients and their crucial role in this regard.

To better understand the relationships between traits and treatments used in this study, Biplot graphs were utilized. The GT biplot method is a powerful tool for evaluating and identifying desirable treatments and genotypes in terms of multiple traits. Biplot analysis visually displays the correlation between traits and enables the evaluation of treatments based on multiple traits. This method also provides information that can be used for indirect selection of dependent traits such as yield. Moreover, this method has been employed for two-way analysis on other plants (Gholizadeh et al., 2018), further supporting its usefulness in analyzing plant performance. The two-dimensional principal component analysis results for different traits (or treatment-trait) and cultivars (Kimia and Sepideh) are shown in Figure 3. The first two components, PC1 = 67.2% and PC2 = 15.4%, explained a total of 82.6% of the variance of variables. To interpret the relationships between traits and treatments, the scores of the first two components were utilized in the Biplot graph. In the Biplot graph, the length and angle between the vectors of traits and treatments (represented by a larger symbol than repetitions) indicate the relationship between traits and treatments in a two-dimensional plot, where the cosine of the angle between the traits is somewhat indicative of the correlation between the two traits in the two-dimensional plane. If two traits have a high correlation with each other, their angle tends towards zero, indicating a strong relationship between them. In Figure 3, the vectors for days to flowering and days to maturity exhibited a high correlation with each other. Most traits were in harmony and aligned with grain yield, indicating moderate to high correlation depending on the acute angle with yield, as shown in the figure. Overall, all repetitions of the Kimia and Sepideh cultivars were included within a limiting ellipse with a confidence level of 95%. These two ellipses did not overlap with each other, signifying different trait behavior between the two cultivars in this study. Sepideh was positioned in the direction of essential economic traits, while Kimia was placed in the direction of phenological traits, indicating an increase in days to flowering and maturity in Kimia compared to Sepideh. These two cultivars represent excellent complementary materials for identifying genes related to the mentioned traits in breeding programs. Leaf area index, thousand kernel weight, and protein percentage exhibited weak correlations with grain yield due to their 90-degree angle.

Figure 4 displays a two-dimensional plot of traits and stress treatments, clearly demonstrating the relationship between traits and stress treatments. All traits, except for plant density, exhibited an inverse relationship with the stress treatment during the vegetative stage. Since plant density was established before the stresses were imposed, stress had little effect on this trait. However, the performance trait was at a borderline for all three stress treatments, indicating the complex nature of this trait under different types of stress, as well as the interaction effect of cultivar and stress. Since the ANOVA table (Table 3) revealed that the interaction effect of stress had a significant impact on the cultivar, a two-dimensional plot of the interaction effect of stress on the cultivar with the mentioned traits was also depicted in Figure 5. In Figure 4, the irrigation treatment is located at the top of the plot and is associated with most traits, while the vegetative stress treatment is situated between the stress treatments during the flowering and normal stages. It seems that the effect of irrigation cessation during the vegetative state had a milder impact, compared to the cessation during the flowering stage. The probable reason for this could be that the plant was able to compensate for water deficiency and damage caused by stress cessation during the vegetative stage earlier than during the flowering stage. Overall, LAI exhibited a negative correlation with stress during both vegetative and flowering stages, with leaf area significantly decreasing as stress increased.

Figure 5 presents a two-dimensional plot of the interaction effect of stress on cultivar with different traits, effectively separating the cultivars and stresses in a two-dimensional graph and displaying the relationship between each group and various traits. The Sepideh cultivar overlaps with the normal stress and irrigation cessation during the vegetative stage, indicating that this cultivar can tolerate stress during the vegetative state, especially in the case of limited irrigation water, as the plant was able to compensate for the damage caused by this stress. Phenological traits, such as days to flowering and maturity in the Kimia cultivar, exhibited a greater increase under stress during the vegetative stage compared to the other two irrigation treatments, indicating the impact of stress during the vegetative stage on extending the growth period of this cultivar. These results are consistent with the results obtained in Figure 2. Overall, this two-dimensional plot provides valuable insights into the interactions between stress and cultivar on various traits, which can be useful for developing stress-tolerant cultivars through breeding programs.

The results of this study indicate that irrigation cessation stress significantly affected many sorghum grain traits, with the best and most desirable conditions observed in the treatment without stress, averaging 7.19 tons per hectare. Stress during the germination stage had a negative effect on both morphological and quantitative traits, whereas stress during the vegetative stage had a less pronounced impact than stress during the germination stage. For instance, under drought stress conditions during the germination stage, the yield of the Sepideh cultivar was approximately 8 tons per hectare, while it was 4.36 tons per hectare for the Kimia cultivar. However, under stress during the germination stage, the yield increased to 7.67 tons per hectare for the Sepideh cultivar and 4.45 tons per hectare for the Kimia cultivar, indicating the interaction effect of stress and cultivar.

In general, almost all measured traits exhibited a significant and positive response to vermicompost fertilizer compared to other fertilizers used. Except for the grain protein percentage, the Sepideh cultivar performed better in all traits (as observed in Figures 1 and 2). This can be attributed to the Sepideh cultivar's favorable response to environmental conditions in Khorramabad. Moreover, cultivar was identified as the most significant factor affecting changes in various traits, exhibiting a high impact on the results. Other factors such as stress and fertilizers mostly received indirect effects under the influence of the cultivar.

The results of this study revealed that the Sepideh cultivar outperformed the Kimia cultivar in terms of all economic traits, except for grain protein content. Furthermore, irrigation cessation during the germination stage had a greater impact on yield traits and yield components compared to irrigation cessation during the vegetative stage. Although the use of fertilizers had a significant effect on various traits in this study, different interactive effects were observed depending on the type of trait. Vermicompost fertilizer had a significant positive effect on forage yield, while chemical fertilizers such as NPK and a combination of NPK and vermicompost fertilizer exhibited superiority over vermicompost fertilizer for grain yield.

Table 1.1. The components of Vermicompost fertilizer used

C/N	Ca(ppm)	Mn(ppm)	B(ppm)	Cu(ppm)	Zn(ppm)	%Fe	%K	%P	%N
12/37	3.37	299.4	75.15	44.55	65.2	0.62	0.81	0.81	1.85

Table 1.2. The characteristics of soil of experiment

Soil Texture	Ca%	pH	EC	Br(ppm)	Zn(ppm)	Mn(ppm)	Fe%	K%	P(ppm)	N%	C%
Sandy-Clay	1.23	7.8	0.5	0.28	0.48	1	1.2	0.52	8	0.130	1.42

Table 1.3. The Components of NPK Chemical Fertilizer

%Other	K%	P%	N%
40	20	20	20

Table 2. Combined Split-factorial analysis of variances of different traits of Sorghum

S.O.V	df	Biological Yield	Day to Flowering	Day to Maturity	Height	Leaf Area Index	Protein Percent	Chlorophyll Index	No. of Plant per Meter	Ear Length	Weight 100 Seed	Grain Yield	Forage Yield	Error term
Year	1	0.009^{ns}	0.001^{ns}	0.082^{ns}	0.01^{ns}	0.039^{ns}	0.137^{ns}	0.053^{ns}	0.034^{ns}	0.07^{ns}	0.134^{ns}	0.314^{ns}	0.067^{ns}	(Rep(Year)) + (Year×Fert) + (Year×Cultivar) - (Year×Fert×Cultivar) - (Residual)
Rep(Year)E1	6	0.047	0.132	0.104	0.017	0.061	0.089	0.057	0.049	0.056	0.066	0.174	0.123	--
Stress	2	168.881*	880.314**	289.756**	3536.218**	5.266^{ns}	19.247**	108.578**	0.065^{ns}	67.881**	0.357^{ns}	18.565**	2.887^{ns}	(Rep(Year×Stress) + (Year×Stress×fert) + (Year×Stress×Cultivar) - (Year×Stress×Fert×Cultivar) - (Residual)
Year×Stress	2	0.112^{ns}	0.161^{ns}	0.175^{ns}	0.08^{ns}	0.022^{ns}	0.022^{ns}	0.361^{ns}	0.057^{ns}	0.066^{ns}	0.025^{ns}	0.083^{ns}	0.004^{ns}	(Rep(Year×Stress)) +(Year×Stress×Fert) +(Year×Stress×Cultivar) - (Year×Stress×Fert×Cultivar) - (Residual)
Rep(Year×Stress)E_2	12	0.089	0.045	0.093	0.096	0.062	0.055	0.219	0.099	0.081	0.085	0.024	0.112	--
Fert	2	0.857^{ns}	69.117**	23.093**	1705.76**	0.07*	5.027*	7.901**	0.141^{ns}	7.887**	0.015^{ns}	0.52^{ns}	7.344**	(year×fert)
Cultivar	1	144.548**	19551**	4965.7**	41435**	0.038^{ns}	66.71**	1331.087**	210.955*	210.211*	0.06^{ns}	423.241*	50.269*	(Year×Cultivar)
Fert×Cultivar	2	0.195^{ns}	10.836*	3.46^{ns}	473.1**	0.014^{ns}	1.182*	0.639*	0.057^{ns}	1.464*	0.017*	1.982^{ns}	1.458**	(Year×Fert×Cultivar)
Stress×Fert	4	0.126^{ns}	0.138*	0.221*	2.584**	0.017^{ns}	0.123^{ns}	0.128^{ns}	0.091^{ns}	0.151^{ns}	0.115^{ns}	0.098^{ns}	0.244*	(Year×stress×Fert)
Stress×Cultivar	2	76.05**	179.79**	43.957**	540.58**	0.146^{ns}	2.25*	1.641**	0.095^{ns}	15.516**	0.087^{ns}	0.618**	0.293^{ns}	(Year×stress×Cultivar)
Stress×Fert×Cultivar	4	0.152^{ns}	0.385^{ns}	0.166^{ns}	1.211**	0.055^{ns}	0.08^{ns}	0.05^{ns}	0.148^{ns}	0.13^{ns}	0.117^{ns}	0.012^{ns}	0.028^{ns}	(Year×Stress×Fert×cultivar)
Year×Fert	2	0.196^{ns}	0.084^{ns}	0.045^{ns}	0.011^{ns}	0.002^{ns}	0.199^{ns}	0.002^{ns}	0.072^{ns}	0.008^{ns}	0.034^{ns}	0.036^{ns}	0.029^{ns}	(Residual)

Year×Cultivar	1	0.004^{ns}	0.024^{ns}	0.131^{ns}	0.354^{ns}	0.001^{ns}	0.005^{ns}	0.06^{ns}	0.145^{ns}	0.065^{ns}	0.005^{ns}	0.148^{ns}	0.239^{ns}	(Year×Fert×Cultivar) + (Year×Stress×Cultivar) - (Year×Stress×Fert×cultivar)
Year×Fert×Cultivar	2	0.101^{ns}	0.228^{ns}	0.185^{ns}	0.005^{ns}	0.046^{ns}	0.012^{ns}	0.009^{ns}	0.065^{ns}	0.032^{ns}	0.001^{ns}	0.155^{ns}	0.013^{ns}	(Year×Stress×Fert×cultivar)
Year×Stress×Fert	4	0.064^{ns}	0.021^{ns}	0.02^{ns}	0.029^{ns}	0.071^{ns}	0.099^{ns}	0.101^{ns}	0.096^{ns}	0.101^{ns}	0.069^{ns}	0.129^{ns}	0.036^{ns}	(Year×Stress×Fert×cultivar)
Year×Stress×Cultivar	2	0.665^{ns}	0.072^{ns}	0.001 ns	0.226ns	0.018 ns	0.066 ns	0.01ns	0.229^{ns}	0.124^{ns}	0.025^{ns}	0.005^{ns}	0.335^{ns}	(Year×Stress×Fert×cultivar)
Year× Stress ×Fert×Cultivar	4	0.122 ns	0.14^{ns}	0.079^{ns}	0.054^{ns}	0.061^{ns}	0.049^{ns}	0.217^{ns}	0.051^{ns}	0.185^{ns}	0.067^{ns}	0.042^{ns}	0.048^{ns}	Residual
Error$_3$	90	0.102	0.099	0.083	0.099	0.069	0.062	0.092	0.117	0.075 ns	0.099	0.081	0.082	

ns, *, ** are non-significant, significant at 5% and 1% probability level, respectively

Table 3. Split-factorial analysis of variances of different traits of Sorghum

S.O.V	df	Biological Yield	Day to Flowering	Day to Maturity	Height	Leaf Area Index	Protein Percent	Chlorophyll Index	No. of Plant per Meter	Ear Length	Weight 100 Seed	Grain Yield	Forage Yield
Stress	2	84.441**	440.157**	144.878**	1768.109**	2.633**	9.624**	54.289**	0.033^{ns}	33.941**	0.179*	9.282**	1.444**
Replication	3	0.007^{ns}	0.01^{ns}	0.093^{ns}	0.015^{ns}	0.059^{ns}	0.082^{ns}	0.042^{ns}	0.026^{ns}	0.025^{ns}	0.054^{ns}	0.051^{ns}	0.121^{ns}
Replication × Stress	6	0.029	0.032	0.037	0.082	0.035	0.017	0.021	0.039	0.049	0.029	0.011	0.072
Fertilizer	2	0.429**	34.559**	11.547**	852.868**	0.035^{ns}	2.513**	3.951**	0.071^{ns}	3.943**	0.007^{ns}	0.26**	3.672**
Cultivar	1	72.274**	9775.69**	2482.851**	20717.37**	0.019^{ns}	33.355**	665.544**	105.478**	105.105**	0.03^{ns}	67.621**	25.134**
Fertilizer ×Cultivar	2	0.097^{ns}	5.418**	1.73**	236.55**	0.007^{ns}	0.591**	0.319**	0.029^{ns}	0.732**	0.009^{ns}	0.991**	0.729**
Stress× Fertilizer	4	0.063^{ns}	0.069^{ns}	0.11^{ns}	1.292**	0.008^{ns}	0.061^{ns}	0.064^{ns}	0.046^{ns}	0.075^{ns}	0.057^{ns}	0.049^{ns}	0.122*
Stress × Cultivar	2	38.025**	89.894**	21.979**	270.288**	0.073^{ns}	1.125**	0.82**	0.047^{ns}	7.758**	0.043^{ns}	0.309**	0.147*
Stress× Fertilizer ×Cultivar	4	0.076^{ns}	0.192**	0.083^{ns}	0.605**	0.027^{ns}	0.04^{ns}	0.025^{ns}	0.074^{ns}	0.065^{ns}	0.059^{ns}	0.006^{ns}	0.014^{ns}
Error	45	0.062	0.046	0.045	0.042	0.032	0.033	0.059	0.051	0.034	0.048	0.037	0.045

ns, *, ** are non-significant, significant at 5% and 1% probability level, respectively

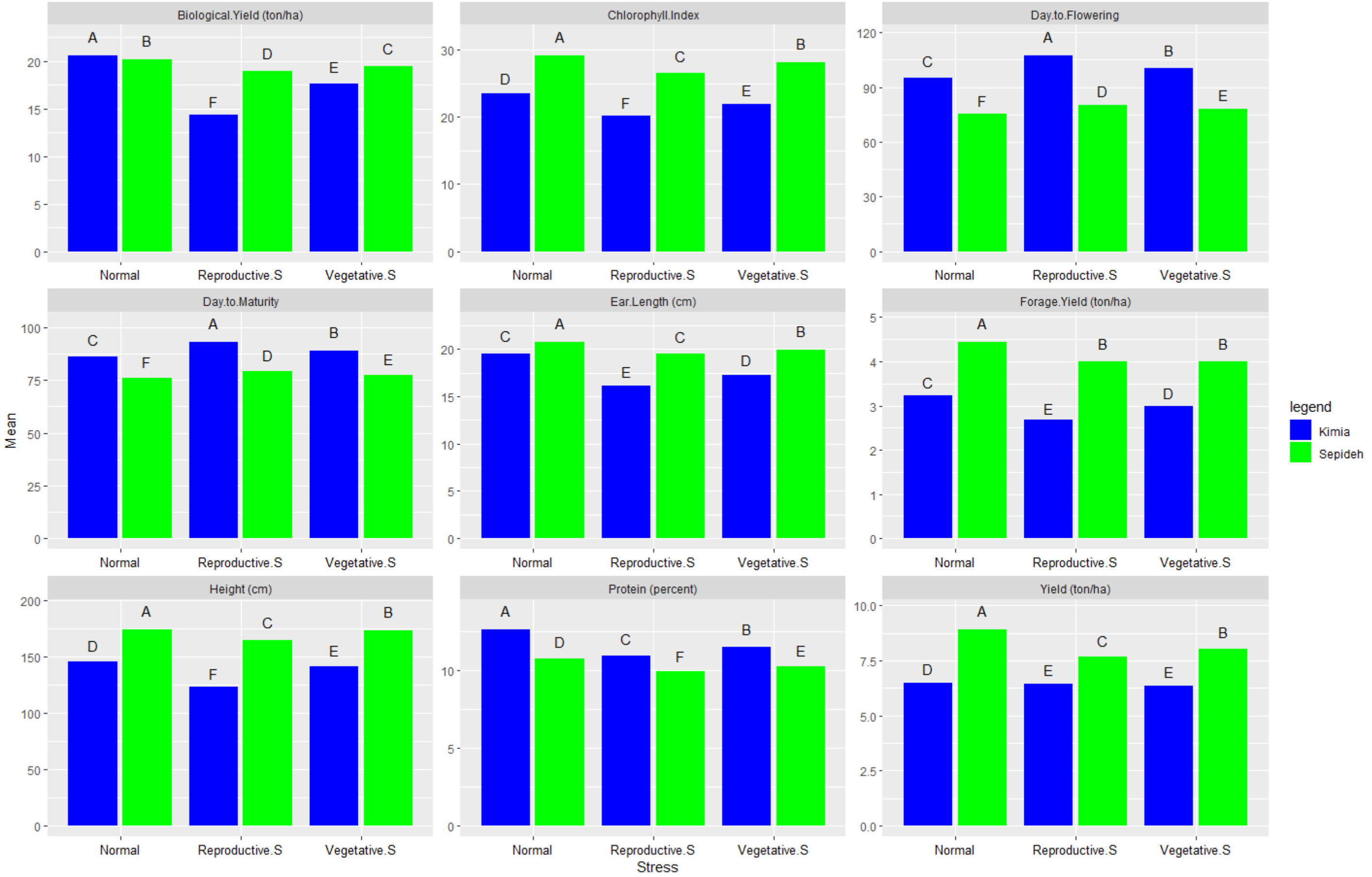

Fig 1. Bar diagram for interaction of Stress ×Cultivar of different traits which had significant effects

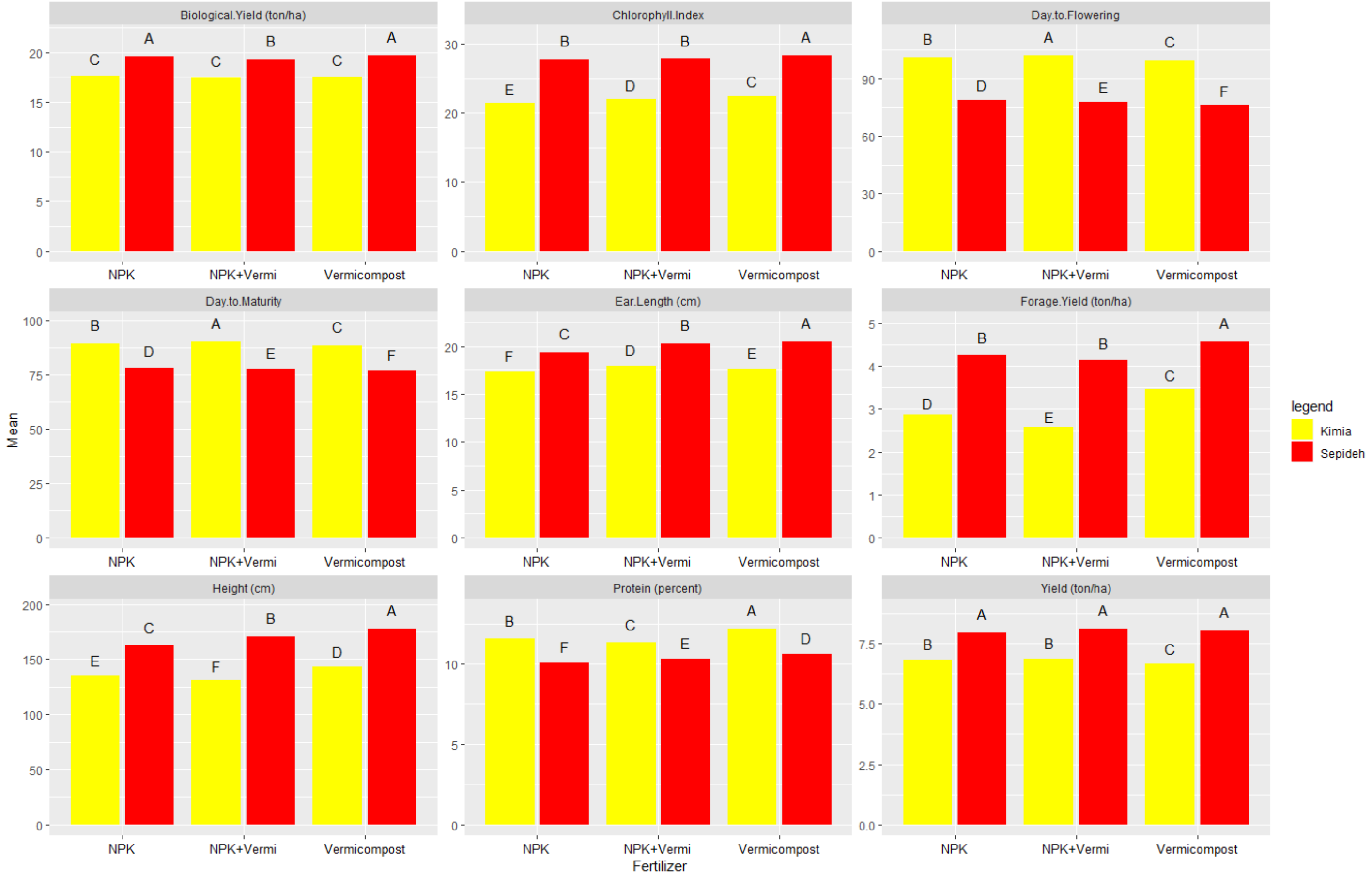

Fig 2. Bar diagram for interaction of Fertilizer ×Cultivar of different traits which had significant effects

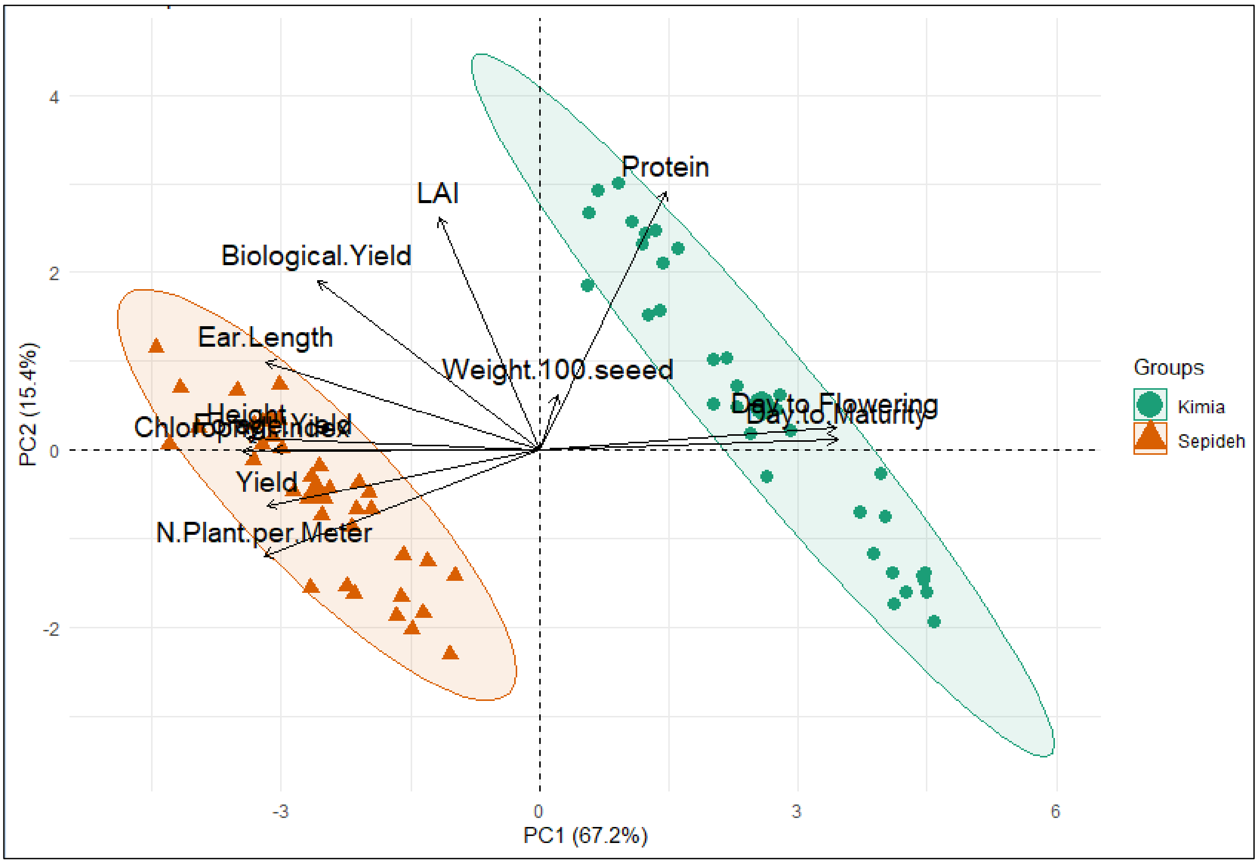

Fig 3. Biplot graph of different traits of Sorghum with Cultivar

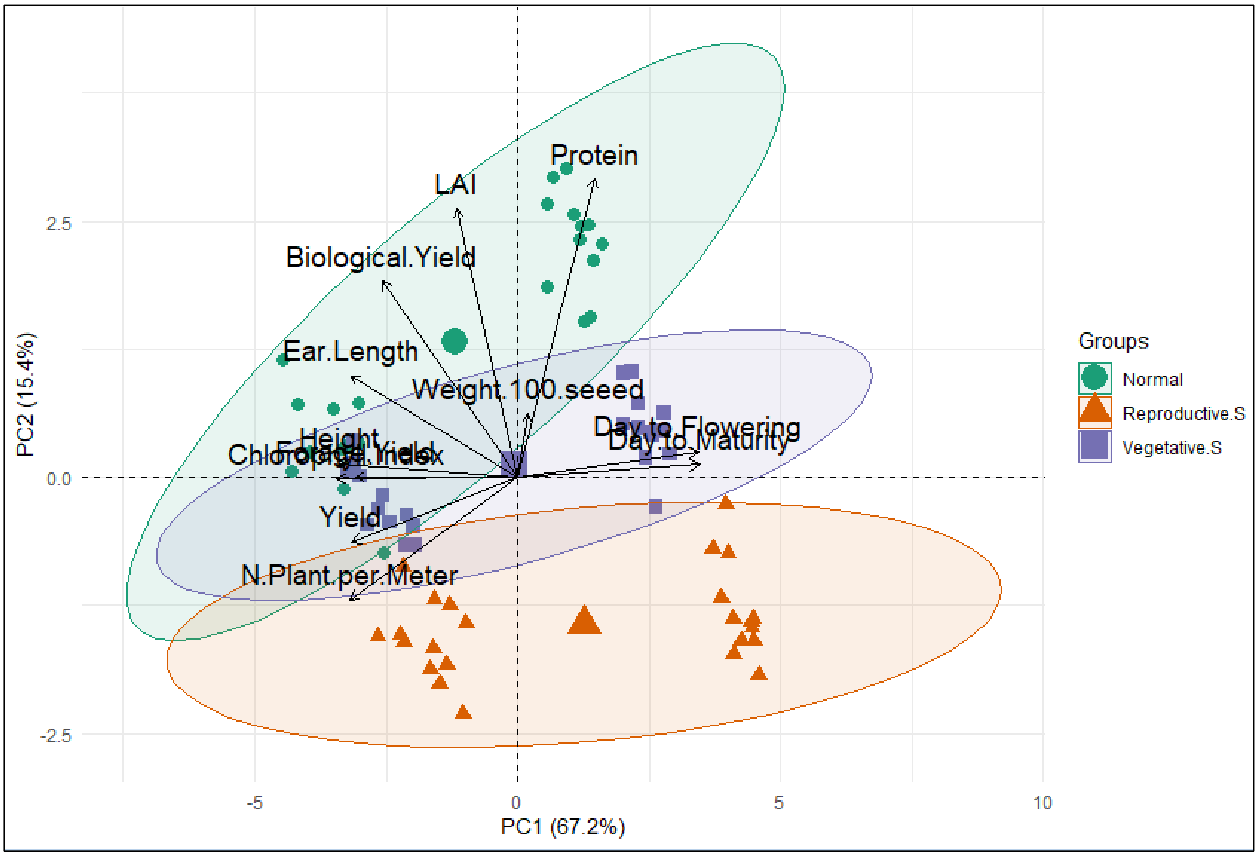

Fig 4. Biplot graph of different traits of Sorghum with Stress treatments

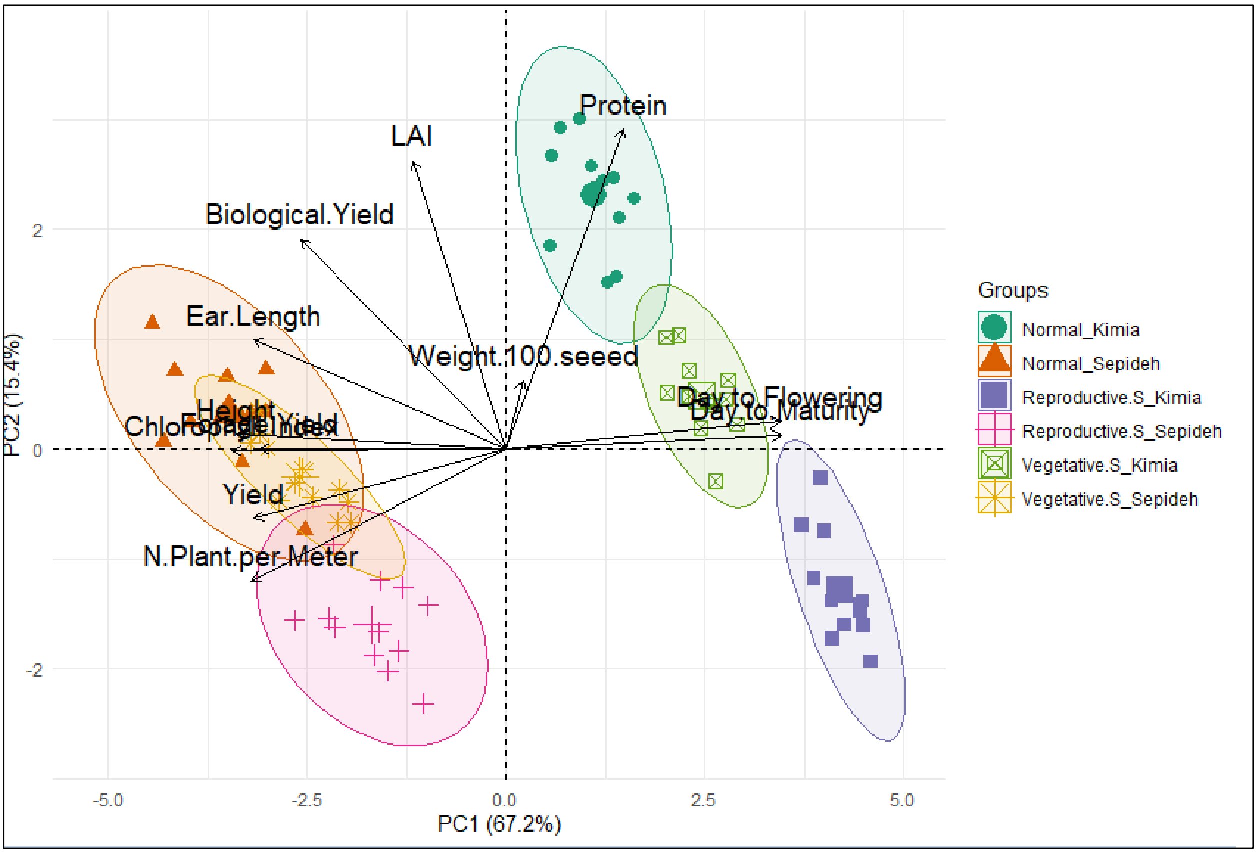

Fig 5. Biplot graph of different traits of Sorghum with Stress treatments by Cultivar

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