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Sowing Dates Effect on the Growth and Grain Yield of Sorghum Genotypes

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Abstract

Sorghum crop is an exceptional food and fodder source. Insightfulness about climate change effects will support researchers to disseminate growers in relation to decide and manage crops and to mitigate hazards. The field experiments were carried out in three replicated RCBD with net plot size 20 m2. The four genotypes such as Bale II, PSC010, Acho Kartuho and Sprout were sown under four sowing dates viz. 18 April, 03 May, 17 May and 31 May to find out effects of sowing dates. Genotypic results for sowing dates and their interactions exhibited highly significant effects at ($P<0.05$) in terms of maximum traits. The genotype Bale II recorded maximum nodes plant, heads plant, head length (cm) and grain weight plant (g). The results for sowing dates also showed that maximum heads plant and head length (cm) obtained under sowing date of 18 April. The maximum nodes plant found with 03 May. The maximum grains plant and grain weight plant (g) recorded under the sowing date of 17 May. The genotypes and sowing dates interactive effects revealed maximum nodes plant obtained under 18 April sown crop with Bale II genotype. The maximum heads plant and head length (cm) gained under 18 April and 31 May sowing dates with genotype Acho Kartuho, respectively. However, maximum grains plant and grain weight plant (g) obtained under 17 May sown crop with Bale II. The concluding aspect indicated that Bale II genotype exhibited better results in accordance with more traits. This study revealed some innovative research areas with momentous effects pertaining to sorghum cultivation establishment for enhancing growth and grain yield traits of sorghum genotypes to overcome the global malnutrition issues.

Keywords: sorghum; sowing dates; biomass; grain; climate

Introduction

Sorghum is extensively sown in wide agro-ecological conditions globally. It possesses high yielding capacity within average environmental condition than any other cereal crops [1], and needed low agro-chemicals [2], [3]. Sorghum genotypes overpowering weeds, nematodes and go in compact subsoil [4]. Sorghum world production was 59.48 million m. tons [5]. In Sindh province, during year 2018 the area sown for sorghum as seed crop was 10205 ha and production was 9473 m. tons. However, as fodder crop the area sown was on 20681 ha and production was 300818 m. tons [6]. There are a range of variables concerned in sorghum crop yield including production differences and countries' dissimilarities at growth, development, and regional climate change effects could mitigate by agricultural venture for enhancing better crop genotypes and improved management [7].

Sorghum belongs from tribe Panicoideae under Andropogoneae [8], [9]. Sorghum genus categorized as sub-genus bicolor, propinquum and halepense. Moreover, S. bicolor included bicolor, drummondi and verticilliflorum [10], [11], [12]. The studies revealed that in natural habitat germ-plasm was originated from Africa [13]. There is certain sorghum genotypes found different colors and diverse classes with grain standard [14] with genetically developed genotypes to produce food. It was published biomass composition, agronomic assessment [15], and indicated that sorghum forages can yield increased biomass for prolonged period of years [16]. As a result, sorghum biomass is added specifically in second generation biofuel production [17]. It was also recommended that agricultural residues could be transformed into bio-pellets, renewable and green source of energy [18].

It was suggested that food supply for the increasing global population, human should find solutions to low contest in terms of food production [19]. The increasing temperature and carbon dioxide affects various plant metabolisms in plant. Indeed, insightful climate change will give a hand to researchers for counseling growers in relation to decide crop management such as crop choices, genotypes, date of sowing, and irrigation for lowering risks [20].

Pakistan's economies depend on agriculture accounts for 19.5% GDP [21]. Increased agriculture production and enhanced yield is crucial for achieving food security which establishes agricultural systems not as much of vulnerable to climate change [22]. Consequently, appropriate variety choice for specific region is imperative for achieving promising results [23]. In addition, most favorable sorghum sowing date is one of prime mechanism to achieve better grain yield. As, crop production is primarily reliant on weather variations; so it plays vital role in climate changes globally on crop production [24]. It was affirmed that selection of crop genotypes, sowing geometry and plant population are key factors of sorghum production [25]. Thus, well-matched technologies can enhance largely farmers' benefits [26]. In the light of above findings, this study research was carried out to unearthed prospective of various genotypes of sorghum with aimed to compare the growth and grain yield traits at field level under different sowing dates as well as to identify interaction that make certain ranking of optimal sorghum production.

Materials and methods

Field experiments were conducted for year 2016 and 2017 at Students' Experimental Farm, Sindh Agriculture University (SAU), Tandojam Pakistan. The ranges of temperature are cold in winter and hot in summer [27]. Disc plough was applied on land then clods were crushed and leveled in soil. Soaking was also applied in soil followed by two plough and leveling was applied. Sorghum seed was drilled for sowing at rate 50 kg ha-1 and kept 60 cm row-spacing. Genotypes viz. Bale II, PSC-1010, Acho Kartuho and Sprout were sown under four sowing dates such as 18 April, 03 May, 17 May and 31 May. The fertilizers applied at rate of 113-41-0 kg NPK ha-1 in form of urea with two doses, 1st at the time of sowing and 2nd at time of first irrigation. However, phosphorus was applied at time of sowing. The four to six irrigations were given as recommended. Interculturing and thinning activities performed at distance of 10 cm. To protect crop herbicide Primextra and hand weeding was applied for controlling weed poulation. While, crop was treated with Carbofuran and Lambda cyhalothrin (recommended) for controlling stem borer [27].

Soil status of experimental field

Soil physico-chemical properties (0-30 cm depth) was determined, and experimented field soil texture was found as clay loam, somewhat saline (pH 8.0-8.5) with organic matter (OM) 0.72-0.73% which was deficient in nitrogen (0.036%), low in phosphorus (0.7-1.8 ppm), and medium in potassium (96-191 ppm).

Meteorological data

The meteorological data was obtained through PMD from minimum to maximum temperature (°C) including rainfall (mm), and relative humidity (%).

Statistical analysis

Data was analyzed statistically through Statistix ver. 8.1, software [28].

Ethical approval

Data is not related to human being or animal, therefore ethical approval is exempted for this research study.

Results

Data was analyzed statistically at (P< 0.05%) probability level in terms of genotypes, sowing dates with interactive effects.

Genotypes' effects

The analysis of variance of genotypes depicted highly significant effects on nodes plant-1, heads plant-1, head length (cm) and grain weight plant-1 (g). However, distance between nodes plant-1 (cm) and grains plant-1 had significant effects. The genotypes effects were found significant for all traits. The results depicted that maximum nodes plant-1 (11.92), heads plant-1 (1.97), head length (22.61 cm) and grain weight plant-1 (19.23 g), were obtained with Bale II genotype. The maximum grains plant-1 (1731.7) was gained with Acho Kartuho. While, maximum distance between nodes plant-1 (14.38 cm) found in Spout (Table 1; Figure 1 and 2).

Table 1: Effect on plant traits by different genotypes of sorghum

Plant traits	Genotypes				S.E.	LSD 5%
	Bale II	PSC-1010	Acho Kartuho	Sprout		
Nodes plant^{-1}	11.92 a	11.24 b	11.34 b	10.98 b	0.2069	0.4225
Heads plant^{-1}	1.70 b	1.69 b	1.97 a	1.54 c	0.0474	0.0969
Distance between nodes plant^{-1} (cm)	13.87 c	13.99 bc	14.26 ab	14.38 a	0.1879	0.3837
Grain weight plant^{-1} (g)	19.23 a	15.03 b	14.57 b	14.46 b	1.2057	2.4624

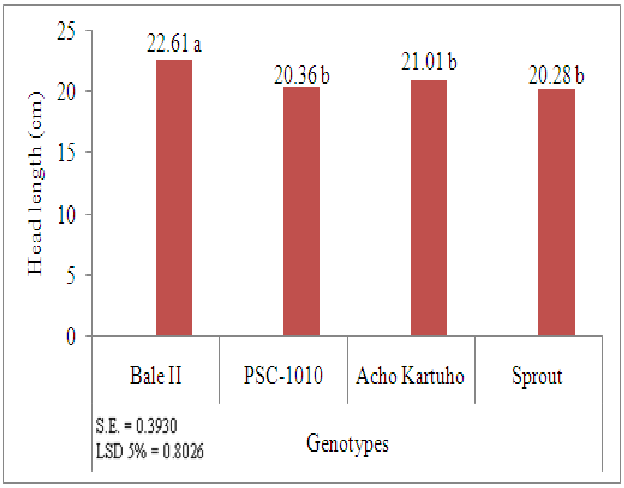

Figure 1: Genotypes' effects on head length (cm)

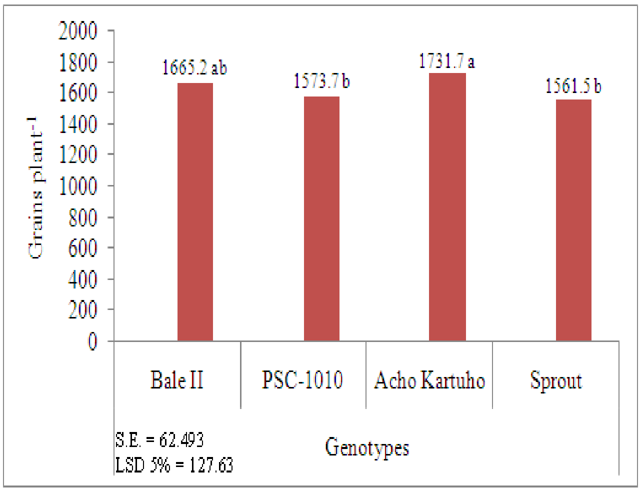

Figure 2: Genotypes' effects on grains plant^{-1}

Sowing dates' effects

For sowing dates the analysis of variance exhibited that nodes plant-1, heads plant-1, distance between nodes plant-1 (cm), head length (cm), grains plant-1 and grain weight plant-1 (g) had highly significant effects. The results depicted that maximum heads plant-1 (1.94) and head length (25.59 cm) obtained under 18 April sown crop. The maximum nodes plant-1 (12.15) noticed with 03 May. The maximum grains plant-1 (2390) and grain weight plant-1 (28.61 g) recorded under sowing date of 17 May. However, maximum distance between nodes plant-1 (15.23 cm) was measured with 31 May sown crop (Table 2; and Figure 3 and 4).

Table 2: Effect on sorghum plant traits by different sowing dates

Plant traits	Sowing dates				S.E.	LSD 5%
	18 April	03 May	17 May	31 May		
Nodes plant^{-1}	11.44 b	12.15 a	11.48 b	11.48 b	0.2069	0.4225
Heads plant^{-1}	1.94 a	1.68 b	1.86 a	1.42 c	0.0474	0.0969
Distance between nodes plant^{-1} (cm)	12.69 d	13.91 c	14.68 b	15.23 a	0.1879	0.3837
Head length (cm)	25.59 a	23.32 b	10.21 c	25.12 a	0.3930	0.8026

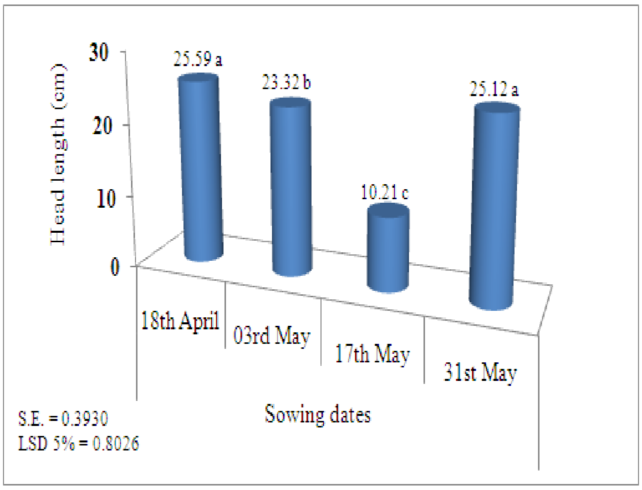

Figure 3: Sowing dates' effects on head length (cm)

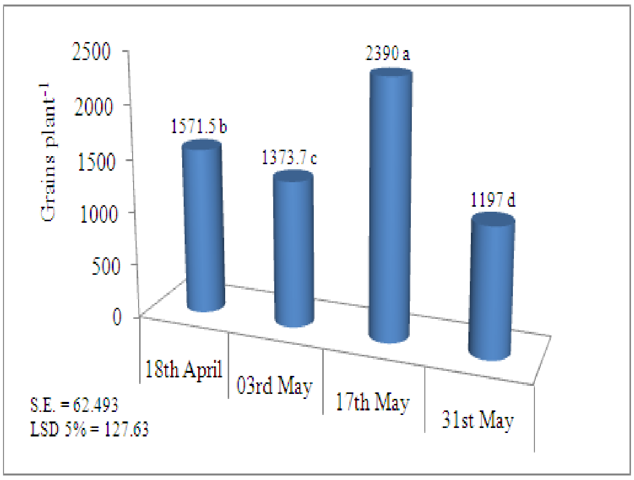

Figure 4: Sowing dates' effects on grains plant^{-1}

Genotypes and sowing dates interactive effects on sorghum plant traits

Genotypes and sowing dates' analysis of variance depicted that nodes plant^{-1}, heads plant^{-1}, distance between nodes plant^{-1} (cm), head length (cm), grains plant^{-1} and grain weight plant^{-1}(g) had highly significant effects. The results revealed that maximum nodes plant^{-1} (12.43) recorded under sowing date of 18 April with Bale II genotype. The maximum heads plant^{-1} (2.8) found with 18 April in Acho Kartuho. The maximum distance between nodes plant^{-1} (16.45 cm) was noticed under sowing date of 31 May in PSC-1010. The maximum head length (27.35 cm) was recorded under 31 May in Acho Kartuho. However, maximum grains plant^{-1}(3233.9) and grain weight plant^{-1}(49.36 g) achieved with 17 May in genotype Bale II; same grains plant^{-1}(3233.9) was also obtained under 17 May sown crop in Sprout (Table 3).

Table 3: Interactive effect on plant traits by genotypes and sowing dates of sorghum

Genotypes	Sowing dates	Nodes plant^{-1}	Heads plant^{-1}	Distance between nodes plant^{-1} (cm)	Head length (cm)	Grains plant^{-1}	Grain weight plant^{-1} (g)
Bale II	18 April	12.43 a	1.33 gh	11.11 i	25.97 abc	978.50 k	7.40 g
	03 May	12.13 abc	1.50 fg	14.71 cd	26.25 ab	1204.70 h-k	10.21 fg
	17 May	11.53 b-e	2.33 b	13.44 fgh	12.16 h	3233.90 a	49.36 a
	31 May	11.57 b-e	1.63 ef	16.23 ab	26.07 ab	1243.90 hij	9.94 fg
PSC-1010	18 April	11.30 c-f	2.03 c	12.91 h	24.22 de	1559.90 efg	13.47 def
	03 May	12.30 ab	2.00 c	12.90 h	24.40 cde	1689.50 def	15.28 cde
	17 May	10.80 efg	1.27 h	13.70 fg	9.74 ij	1734.60 de	20.19 c
	31 May	10.57 fg	1.47 fg	16.45 a	23.07 ef	1310.70 ghi	11.17 efg
Acho Kartuho	18 April	11.20 def	2.80 a	13.75 fg	25.28 bcd	2390.60 c	19.88 c
	03 May	12.37 ab	1.77 de	14.14 def	21.09 g	1441.30 fgh	9.72 fg
	17 May	11.57 b-e	1.97 c	15.47 bc	10.30 i	1906.80 d	17.85 cd
	31 May	10.23 g	1.33 gh	13.69 fg	27.35 a	1188.10 h-k	10.80 efg
Sprout	18 April	10.83 efg	1.60 ef	13.01 gh	26.91 a	1356.90 ghi	10.18 fg
	03 May	11.80 a-d	1.47 fg	13.87 ef	21.55 fg	1159.20 ijk	10.69 efg
	17 May	12.00 a-d	1.87 cd	16.12 ab	8.65 j	3233.90 a	27.04 b
	31st May	9.30 h	1.23 h	14.54 de	23.99 de	1045.10 jk	9.94 fg
S.E.		0.4137	0.0949	0.3758	0.7860	124.99	2.4115
LSD 5%		0.8449	0.1937	0.7674	1.6053	255.25	4.9249

Discussion

The genotypic performance resulted maximum nodes plant^{-1}, head length (cm), and grain weight plant^{-1}(g) obtained in genotype Bale II. The maximum plants count (m^2) was noticed in PSC-1010. While, maximum grains plant^{-1}were obtained with Acho Kartuho. The maximum distance between nodes plant^{-1} (cm) was found in Spout. However, sowing dates effects indicated that nodes plant^{-1}, heads plant^{-1}, distance between nodes plant^{-1} (cm), head length (cm), grains plant^{-1}, and grain weight plant^{-1}(g) had highly significant effect. These finding were corroborated with previous results that the sweet sorghum potential that is directly affected through sowing dates [29].

The results exhibited maximum heads plant^{-1} and head length (cm) found under 18 April sown crop. The close agreement revealed by these results and with Late sown sorghum resulted growth reduction that reduced photo period, water absorption, and nutrition in sorghum plants [30]. It was indicated that low yield the prime apprehension in sorghum grain yield. This dilemma persuade due to integrated management, genetics and various environmental drivers [31]. Despite of this, late sown crop with warm summer month of May performed enhanced productivity in terms of maximum nodes plant^{-1} obtained with 03 May.

The maximum grains plant^{-1} and grain weight plant^{-1}(g) achieved with 17 May sown crop. While, maximum distance between nodes plant^{-1} (cm) was noticed with 31 May. The results are confirmed by [32] and [33] who revealed that sorghum is better option than other grains in areas with limited precipitation and unaffordable irrigation.

The interaction between genotypes and sowing dates had highly significant effects on nodes plant^{-1}, heads plant^{-1}, distance between nodes plant^{-1} (cm), head length (cm), grains plant^{-1} and grain weight plant^{-1}(g). The maximum nodes plant^{-1} found under sowing date of 18 April in genotype Bale II. The maximum heads plant^{-1} noticed under 18 April in Acho Kartuho. The maximum distance between nodes plant^{-1} (cm) was found with 31 May sown crop in PSC-1010. The maximum head length (cm) was recorded under 31 May in Acho Kartuho. The sowing dates indicated significant effect on head length [34]. The maximum grains plant^{-1} and grain weight plant^{-1}(g) achieved under 17 May in Bale II. In addition, maximum grains plant^{-1}was also found with 17 May sown crop in Sprout as well.

These findings indicated that sowing dates had highly significant effects on most of sorghum plant traits. It was stated that sorghum output allied with atmosphere and genotype [35]. The planting time relied on area's climatic circumstances and sowing variety. The delayed sowing, caused seed yield reduction was noticed owing to photoperiod effect, temperature and rainfall [36]. Water supply projection of certain areas would be reduced owing to unstable precipitation, extended and reduced intervals of rainy season during growth period of crop [37]. Similar perception about genotypes of sorghum response to various techniques (sowing dates variation) noticed regarding efficient techniques strategies to achieve increased yield [38]. Thus, it is affirmed that sorghum is best option than other cereals [39], and the demand for increasing grain yield is being not only increased for feed but also for food [40].

Conclusion

The genotype Bale II well resulted almost with all traits and achieved maximum nodes plant^{-1}, heads plant^{-1}, head length (cm) and grain weight plant^{-1} (g). The sowing dates results revealed that maximum grains plant^{-1} and grain weight plant^{-1} (g) found with 17 May sown crop. The genotypes and sowing dates interactive effects produced maximum nodes plant^{-1} under 18 April in Bale II. The maximum grains plant^{-1}and grain weight plant^{-1}(g) were also gained with 17 May in Bale II. Consequently, Bale II is recommended with 17 May sown crop to obtain maximum growth and grain yield traits of sorghum.

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Conflict of interest

There is no conflict of interest as stated by the authors.

References

1. Mohamed SS. Genetic Diversity among some Sudanese Sorghum Accessions using Molecular Markers and Phenotypic characterization. Thesis of Msc-Sudan Academy of Sciences 2011.
2. Sher A, Ansar M, Hassan F, Shabbir G, Malik MA. Hydrocyanic acid contents variation amongst sorghum cultivars grown with varying seed rates and nitrogen levels. International Journal of Agriculture and Biology 2012, 14, 720-726.
3. Serna-Saldivar SO, Chuck CH, Perez EC, Heredia EO. Sorghum as a multifunctional crop for the production of fuel ethanol: current status and future trends. In: Bioethanol (eds Lima MAP, Natalense APP). InTech. Rijeta, 2012 Croatia: 51-74.
4. Clark A. Managing cover crops profitably, 3rd ed. National SARE Outreach Handbook Series Book 9 2007. Natl. Agric. Lab., Beltsville, MD.
5. United States Department of Agriculture (USDA). Available from: http://www.usda.gov [Accessed on July 7, 2020]
6. CRSC (Crop Reporting Service Centre). Final estimate of jowar crop and all kharif fodders of Sindh province for the year 2018. Crop Reporting Service Centre, Government of Sindh, Hyderabad.
7. Clara WM, Secchi S, Akamani K, Wang G. A regional comparison of factors affecting global sorghum production: The case of North America, Asia and Africa's Sahel, Sustainability 2019, 11, 2135. DOI:10.3390/su11072135.
8. Kellogg EA. Phylogenetic relationships of saccharinae and sorghinae. In: Paterson HA, editor. Genomics of the Saccharinae. New York: Springer 2014, 3-21.
9. Rao PS, Kumar CG, Reddy BVS. Sweet sorghum: from theory to practice. In: Rao PS, Kumar CG, editors. Characterization of improved sweet sorghum cultivars. Berlin: Springer 2012, 1-15.
10. Wet JMJ. 1978. Systematics and evolution of Sorghum sect. sorghum (Gramineae). American Journal of Botany 1978, 65 (4), 477-84.
11. Wiersema JH, Dahlberg J. The nomenclature of *Sorghum bicolor*(L.) Moench (Gramineae). Taxon 2007, 56, 941-6.
12. Mekbib F. Farmers' breeding of sorghum in the centre of diversity, Ethiopia: I. Socio-ecotype differentiation, varietal mixture and selection efficiency. Maydica 2009, 54, 25-37.
13. Baidab SFA. Preparation of Hulu. Mur Flavored Carbonated Beverage Based on sorghum (*Sorghum bicolor*) Malt. Thesis of Msc. Sudan Academy of Sciences 2012.
14. Dahlberg J, Berenji J. Assessing sorghum germplasm for new traits: food and fuels. Maydica 156-1750. Advance Access Publication 2011, 85-92.
15. Yu JL, Zhong J, Zhang X, Tan TW. Ethanol production from H_2SO-steam-pretreated fresh sweet sorghum stem by simultaneous saccharification and fermentation. Applied Biochemistry and Biotechnology 2008, 1-9.
16. May A, Vander FS. Plant population and row spacing on biomass sorghum yield performance. Ciencia Rural 2016, 46 (3), 434-439.
17. Musaida N, Charles M, Edison M. Biomass pellets for application as an alternative solid fuel in Southern Africa: A Review. Proceedings of the DII-2017 Conference on Infrastructure Development and Investment Strategies for Africa: Infrastructure and Sustainable Development-Impact of regulatory and institutional framework. 30 August-1 September 2017, Livingstone, Zambia. ResearchGate. ISBN 978-0-620-74121-7, 249-256.
18. Wanbin Z, Torbj Orna OL, Akan HO, Maogui W, Bjorn H, Jiwei R, Guanghui X, Shaojun X. Cassava stems: a new resource to increase food and fuel production. Global Change Biology. Bioenergy 2013. DOI: 10.1111/gcbb.12112. 7:72-83
19. Patricia OD, Yeboah S, Addy SNT, Amponsah S, Owusu ED. Crop modeling: A tool for agricultural research. A Review. E3 Journal of Agricultural Research and Development 2012, 2 (1), 001-006.
20. Usman H. The Express Tribune. Pakistan's Agriculture Productivity among the Lowest in the World 2018. Available from: https://tribune.com.pk /story/1616347/2-pakistans-agriculture-productivity-among-lowest-world [Accessed on April 04, 2019].
21. Pakistan Bureau of Statistics. Pakistan Economic Survey-Agriculture, Chapter 2, 2014, 15, 1-2.
22. Mathur S, Umakanth AV, Tonapi VA, Rita S, Manoj KS. Sweet sorghum as biofuel feedstock: Recent advances and available resources. Biotechnology for biofuel 2016, 10, 146, 1-19. DOI: 10.1186/s13068-017-0834-9
23. Murthy VRK. Crop growth modeling and its applications in agricultural meteorology. Satellite Remote Sensing and GIS Applications in Agricultural Meteorology 2002, 235-261.
24. Thapa S, Stewart BA, Xue Q, Chen Y. Manipulating plant geometry to improve microclimate, grain yield, and harvest index in grain sorghum. Plos One 2017, 12 (3), e0173511. DOI:10.1371/journal.pone.0173511.
25. Qin J, Impa SM, Qiyuan T, Shenghai Y, Jiang Y, Yousheng T, Krishna SVJ. Integrated nutrient, water and other agronomic options to enhance rice grain yield and N use efficiency in double season rice crop. Field Crops Research 2013, 148, 15-23.
26. Pakistan Meteorological Department (PMD). Monthly climatic normal of Pakistan, 1981-2010 (January 2013); Climatic Data Processing Centre, Karachi.
27. Sindh Zarat. Crop cultivation calendar. Monthly magazine, Sindh Zaraat, January 2018 (regional language): 15-19.
28. Statistix. Statistix 8 user guide, version 1.0. Analytical Software, PO Box 12185, Tallahassee FL 32317 USA. Copyright 2006 by Analytical Software.
29. Rao SS, Patil JV, Prasad PVV, Reddy DCS, Mishra JS, Umakanth AV, Reddy BVS, Kumar AA. Sweet sorghum planting effects on stalk yield and sugar quality in semi-arid tropical environment. Agronomy Journal 2013, 105 (5), 1458–65.
30. Athar M. Performance of Sorghum (*Sorghum bicolor*L. Moench) as an Energy Crop for Biogas

Production. PhD thesis dissertation in Faculty of Agricultural and Nutritional Sciences, Home Economics and Environmental Management Justus Liebig University Giessen, Germany 2012.

31. McHenry B, Adee E, Kimball JP, Vara PV, Ciampitti IA. Balanced Nutrition and Crop Production Practices for Closing Sorghum Yield Gaps, Kansas Agricultural Experiment Station Research Reports 2016, 2, Iss. 5. DOI: org/10.4148/2378-5977.1219
32. Nedumaran S, Abinaya P, Bantilan MCS. Sorghum and millets futures in Asia under changing socio-economic and climate scenarios. Socioeconomics Disc. 2013 Paper Ser. No. 2. ICRISAT Publications, Patancheru, India.
33. Reddy BVS, Kumar AA, Sharma HC, Rao SP, Blummel M, Reddy C, Sharma R, Deshpande SP, Mazumdar SD, Dinakaran E. Sorghum improvement (1980–2010): Status and way forward. Journal of Semi-Arid Tropics (SAT) Agricultural Research 2012, 10, 1-14.
34. Abdel Rahman A, Mohamed EL, Abuel Hassan SI. Effects of Sowing date, cultivar and nitrogen application on ratoon cropping of grain sorghum. Sudan Journal of Agricultural Research 2005, 5, 13-18.
35. Menezes CBD, Adenilson DSR, Flavio DT, Abner JDC, Edson AB, JC Milton, Arley FP, Karla JDS, Crislene VDS, Flavio HLA. Sorgh line adaptability and stability in environments with and without water restriction. Revista Brasileira De Milho E Sorgo 2015, 14, 1, 101-115.
36. Jaybhaye PR, Shinde PB, Asewar BV. Response of soybean to sowing dates and spacing under rainfed condition. International Journal of Tropical Agriculture 2014, 33, 2, 747-750.
37. Allen CD, Macalady AK, Chenchouni H, Bachelet D, McDowell N, Vennetier M. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. Forest Ecology and Management 2010, 259, 660-684.
38. Fiorini IVA, Von Pinho RG, Santos AO, Borges ID, Pires LPM, Resende EL, Pereira HD. Influence of populations, sowing and cutting times on yield of sorghum. BRS 506. Revista Brasileira de Milho e Sorgo 2016, 15, 1, 94-104.
39. Borghi E, Crusciol CAC, Nascente AS, Sousa VV, Martins PO, Mateus GP, Costa C. Sorghum grain yield, forage biomass production and revenue as affected by intercropping time. European Journal of Agronomy 2013, 51, 130-139.
40. Sivakumar S, Xin L, Xianran L, Z Chengsong, Guihua B, Ramasamy B, Mitchell RT, Vara PV, Sharon EM, Tesfaye TT, Jianming Y. QTL mapping for grain yield, flowering time and stay-green traits in sorghum with genotyping-by-sequencing markers. Crop Science 2016, 56, 1429-1442.