Nat. Volatiles & Essent. Oils, 2022; 9(2): 675-686

NVEO
Natural Volatiles &
Essential Oils

Studies On Irrigation Management For A Recently Developed Cotton Variety, Sindh-1

Muhammad Akbar Zardari[1*] , Aijaz Ahmed Soomro[1] , Muhammad Nawaz Kandhro[1] , Namatullah Laghari[2]

1. Department of Agronomy, Sindh Agricultural University, Tandojam, Pakistan.
2. Department of Farm Power & Machinery, Sindh Agricultural University Tandojam, Pakistan.

ABSTRACT

Cotton is considered as backbone of Pakistan's textile industry; because this industry predominantly depends upon cotton crop for raw material to manufacture fibre and clothes. Cotton seed is the principal source of edible oil production that is the major contributor to the domestically produced total edible oil. Therefore, the current field study has been framed to categorize the irrigation frequencies with reference to growth and yield enhancement in newly developed cotton variety 'Sindh-1' in mitigating the major challenge of irrigation water especially during summer season. Four irrigation regimes (7 irrigations: 30, 45, 60, 75, 90, 105 and 120 DAS; 6 irrigations: 30, 50, 70, 90, 110 and 130 DAS [the existing recommendation]; 5 irrigations: 30, 55, 80, 105, 130 DAS; and 4 irrigations: 30, 60, 90 and 120 DAS) were tested. The results showed that cotton performed economically better when supplied with five irrigations as compared to six and seven irrigations in terms of weight boll^{-1} (3.38, 3.32, 3.06 g), seed cotton weight plant^{-1} (137, 136.14, 125.32 g), seed weight plant^{-1} (87.68, 85.21, 80.20 g), lint weight plant^{-1} (49.93, 47.32, 45.12 g), seed cotton yield ha^{-1} (3287.4, 3216.9, 3007.8 kg), seed yield ha^{-1} (2128.5, 2068.2, 1921.6 kg) and, lint yield ha^{-1} (1158.9, 1148.7, 1086.2 kg). The study concluded that cotton crop could economically be managed under reduced irrigation (5 irrigations) against existing recommended irrigation times (6 irrigations) to cope with water shortage in summer season for Kharif crops particularly for cotton variety Sindh-1.

Keywords: Cotton, variety Sindh-1, irrigation optimization, growth, seed, lint yield, quality

INTRODUCTION

Cotton (Gossypium hirsutum L.) is widely cultivated as a profitable fiber crop in Pakistan and is considered as the potential source of sustainable development for national economy. Meanwhile, the global textile industry is also mainly based on cotton fibre and this crop is also a major source of edible oil production (Rehman et al., 2019). Pakistan ranks 4th globally in cotton production (1785 thousand tons) after India, China, United States and Brazil producing 6205, 5987, 4555 and 1894 thousand tons, respectively (Statista, 2018). During 2020-21, cotton crop was sown on an area of 2,079 thousand hectares showing 17.4% decrease over the previous year's area (2,517 thousand ha). During 2020-21, the national production remained 7.064 million bales showing 22.8% decrease over the previous year's production of 9.149 million bales. Presently, the average seed yield of cotton is 578 kg ha^{-1}, indicating 6.5% decrease over last year's yield (618 kg ha^{-1}). This implies that the decrease in cotton production is not only associated with the decline in area under cotton crop, but there was a significant decrease in seed yield ha^{-1}. The flaws in government policies on cotton price and lack of incentives to growers remained the main causes; while use of unapproved cotton varieties have also added to this deteriorated situation. Moreover, an increased water shortage during the sowing season and later at critical growth stages also contributed to this adverse situation (Economic Survey of Pakistan, 2021). Probably, an exorbitant imported seed was used which was unsuitable for the local environment, coupled with lack of expertise on the farmers' side (Shuli et al. 2018; Feng et al., 2020). Potentially, the annual cotton production could normally be achieved upto 20 million bales; and by introduction of domestically evolved cotton seed, scientists are striving to achieve this output target (GoP, 2019).

Farmers have widely adopted Bt cotton since its first trial in Sindh province in 2002; and Bt cotton now covers more than 95 percent of the total area under cotton cultivation in Pakistan. The approved cotton varieties in Punjab and Sindh included 12 Bt varieties and six non-Bt varieties (PCPA, 2015). In Sindh province, indigenous varieties of cotton are also grown but the area under cultivation of local varieties has shown rapid decrease due to popularity of Bt cotton varieties (Dawn, 2012). Fatima et al. (2016) reported that in Pakistan, the non-Bt cotton varieties have been promptly substituted with the Bt cotton varieties. This substitution of imported Bt cotton seed is taking place without even considering the local environmental conditions. The principal reason for the introduction of Bt cotton was its ability to resistthe most dreaded cotton pests; despite of so many controversies surrounding its cultivation. Bt cotton technology adoption has been inconsistent and inappropriate; and most farmers have failed to provide an agriculture production regime needed to keep the technology effective (Maharana et al., 2011). On the other hand, the menace of fake Bt cotton seed in the agriculture market has challenged the growers and scientists in actually achieving the desired benefits of Bt cotton (Sarwar et al., 2012). Apart from varietal issues, shortage of irrigation water has also limited cotton yield worldwide (Schofield and Haigh, 2017).

Cotton crop is sensitive to soil moisture availability; and irrigated agriculture is facing acute competition for low cost water (Howell et al., 2004; Xi-ping et al. 2004). Pakistan is located in the water scarce region; while the entire economy of the country is backboned by agriculture. The country faces water shortages during monsoon, post monsoon and winter seasons. The existing situation demands to use modern technologies for agriculture production by adoption of water saving technologies developed by China (Economic Survey of Pakistan, 2021) or elsewhere. Better irrigation water use efficiency can be achieved through adoption of crop varieties with drought resistance (Goyne and McIntyre, 2001); but lack of drought resistant varieties coupled with less effective water management techniques are critical issues especially in cotton growing areas of Pakistan (Bhattarai, 2005; Khan et al. 2011). Aujla et al. (2005) and Jalota et al. (2006) emphasized that an efficient irrigation system and drouight resistant varieties are pivotal in achieving the desired agronomic yield in cotton under water deficit conditions. It is based on estimating the soil water content in the crop root zone viewed as a system (Abdel-Malak, 2005; Harris, 2005). Avoiding irrigation during the vegetative growth stages could result decreased yields substantially; while proper irrigation management could lead to improved irrigation water use efficiency (Garcia et al. 2010). Most of the crops in Pakistan are produced under irrigated conditions; thus, it is essential to determine the water regimes leading to improved crop yields and irrigation efficiency

(Khan et al. 2011). In practice, over irrigation is done by farmers due to lack of awareness about the crop water requirements under the fixed interval system of water distribution. Such an excessive use of water can also adversely affect the crop yield (English et al. 2002).

Considering the above scenario, it was hypothesized that cotton growth and yield related traits might be economically maximized by adopting proper irrigation management thus the study was carried out to optimize irrigation water requirement of a newly evolved cotton variety Sindh-1.

MATERIALS AND METHODS

The experimental field was situated in the premises of Agriculture Research Center (ARC) Tandojam, Sindh (25°26'^{O} N latitude and 68°32'^{O} E longitude). The trials were conducted during Kharif seasons of 2017 and 2018. Initially, the land was worked with two dry plowings, followed by heavy soaking dose. When soil reached field capacity, precision leveling of land was done, followed by two cross-wise cultivator plows and planking with Patio to achieve fine seedbed. Cotton variety Sindh-1 (a newly developed promising local cotton variety) was used to optimize its requirements for irrigation water. The sowing was done in 1st week of May in a plot size of 5 m x 3 m (15 m^2) keeping 30 and 75 cm intra and inter row spacings. The seed was sown by drilling method in RCBD (factorial) with three replicates. The NPK fertilizers were applied as per the official recommendation. All P and K in addition to half N were applied as basal application in the form of DAP, SOP and urea; while the remaining N was applied in two splits. Similarly, the crop was irrigated as per the treatments plan. The recommended plant protection measures for control of weeds, insect pests and diseases were taken. Lambda 200SL and Radiant/ 120SC were applied against sucking type pests; while Coragen 120SC was used to control bollworm. The 1st picking was done at the time of 50% boll opening and subsequent pickings (2nd and 3rd) were carried out at 15 to 20 days interval.

Observations/procedures

Soil analysis

Soil texture was determined by Bouyoucos Hydrometer method by Bouyoucos (1962); while EC was analysed by digital conductivity meter. Diagnosis and Improvement of Saline and Alkali Soils. Agri. Hand Book No.60. USDA (1954). Method No.3c.P. 88. For knowing soil pH, digital pH meter, model SP-34 Suntex was used as suggested by Practical, Agri. Chemistry Kanwar and Chopra (1959); while the soil OM was determined by Walkely-Black method as described in soil chemical analysis by Jackson (1958) method No.9.65-68.p, 220. Total N was determined by Kjedahl method as described in soil chemical analysis by (1958) method No. 84 (p183); while available P and extractable K were determined by By AB-DTPA method of Soltanpour and Sehwab (1985) using spectrophotometer.

Agronomic indices

The agronomic indexes including plant height was recorded by measuring tape while monopodial and sympodial branches, total bolls, opened/unopened plant^{-1} were recorded by visual counting from the randomly selected five plants. Seed-cotton weight, seed weight and lint weight were recorded on the basis of 20 bolls from each plot using electronic top loading balance and then average was calculated. The seed-cotton weight, seed weight and lint plant^{-1} were measured on the basis of randomly selected five plants in each sub-plot and averaged. After separating the seed from seed cotton by ginning, 1000 seeds were taken at random from each treatment of three replications and weighed as seed index. To obtain total seed cotton yield, the seed cotton obtained from each treatment of three replications was weighed and mean was calculated for one plot and then converted to per hectare. The staple length (mm) was determined by combining the fiber and was measured by a graduated plastic disc; while to record ginning out turn (GOT), seed cotton was ginned by electronic ginner in Cotton Section, Agriculture Research Institute, Tandojam. The lint and seed was weighed separately and the weight of lint was multiplied by hundred and divided by the weight of seed + lint. The percentage was calculated and expressed as GOT %. For oil content, five to ten seeds of cotton were taken and weighed. The oil was extracted through soxhelete apparatus and extracted oil was measured, then oil % was calculated.

Statistical analysis:
The collected data were subject to statistical analysis using Statistix 8.1computer software (Statistix, 2006). The LSD test was applied to compare treatments superiority, where necessary.

Soil analysis
The soil texture of the experimental site at 0-15 cm and 15-30 cm depths was sandy clay; and the sand content was higher at 15-30 cm soil depth as compared to 0-15 cm soil depth (Table-1).

Table 1: Soil texture at different depths

Soil depths (cm)	Sand (%)	Silt (%)	Clay (%)	Texture Class
0-15	45.78	12.55	41.67	Sandy Clay
15-30	47.08	12.34	40.58	Sandy Clay

Soil classification: Heavy: Clay, Silty Clay and Clay Loam (Brady, 1990)
Medium: Silty, Silty Loam, Loam, Silty Clay Loam, Sandy Clay Loam and Sandy Clay
Light: Sandy, Sandy Loam, Loamy Sand (Brady, 1990)

Data regarding the soil physico-chemical properties in the composite samples obtained from the experimental soil for cotton planting are given in Table 2. According to the results, before sowing, the soil had average pH value of 7.08, EC 0.36 dSm^{-1}, OM 0.87%, $CaCO_3$ 11.50 %, total N 0.047%, available P 0.036% and extractable K 11.36%. The soil samples from the same fields were once again collected after harvesting/picking of cotton crop and evaluated for the same properties. After harvesting, soil had an average pH value of 7.90, EC 0.66 dSm^{-1}, OM 1.92%, $CaCO_3$ 6.30%, total N 0.058%, available P 0.86% and extractable K 26.80%. After harvesting of cotton, the soil was appreciably improved in soil physico-chemical properties. The pH was slightly increased but was within the recommended limit of suitability for crop production. $CaCO_3$, total N, available P and extractable K were improved noticeably. This shows that proper scheduling of irrigation and application of optimum dose and time of NPK fertilizers showed positive impacts on soil fertility.

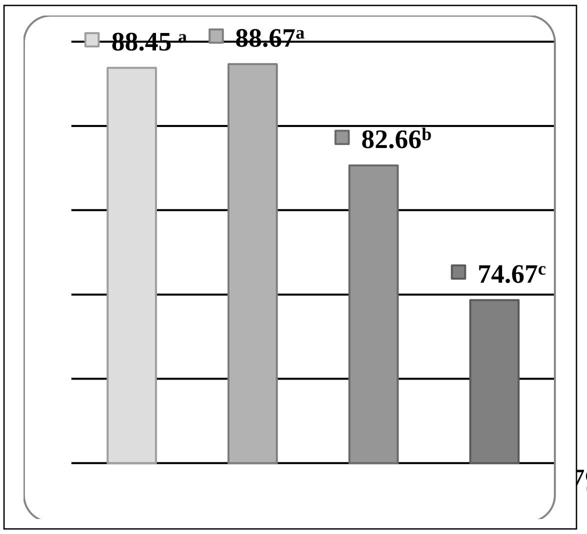
Table 2: Physico-chemical properties of experimental soil before sowing and after picking of cotton

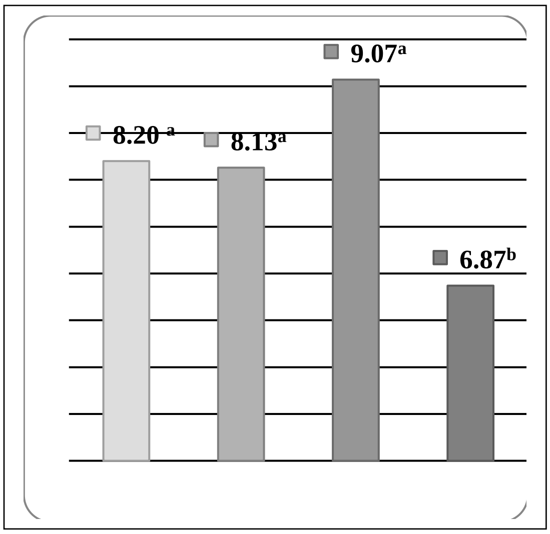
Properties	Before sowing	After picking
pH	7.08	7.90
EC (dS/m^2)	0.36	0.66
O.M (%)	0.87	1.92
$CaCO_3$ (%)	11.50	6.30
Total N (%)	0.047	0.058
Available P (%)	0.036	0.86
Extractable K (%)	11.36	26.80

RESULTS

This study attempts to optimize the number of irrigations for cotton variety Sindh-1 to thrive under local conditions by assessing the crop response in terms of plant growth, seed cotton and lint yield, lint quality and oil content. The data (Fig 1-15) depicted that plant height of cotton under seven irrigations (88.45 cm) and six irrigations (88.67 cm) was statistically at par (P>0.05); while it declined under five irrigations (82.66 cm) and four irrigations (74.67 cm). The maximum values of sympodia (9.07), monopodia (1.53) and opened bolls plant^{-1} (20.27) while the lowest number of unopened bolls (3.73 plant^{-1}) were observed under five irrigations. The sympodia, monopodia and opened bolls plant^{-1} were reduced a little in comparison with five irrigations when the crop received six or seven irrigations (P>0.05).

The results further revealed that most of the agronomic indices responded more positively to five irrigations than six and seven irrigations; such as seed cotton weight boll^{-1} (3.38, 3.32, 3.06 g), seed cotton weight plant^{-1} (137, 136.14, 125.32 g), seed weight plant^{-1} (87.68, 85.21, 80.20 g), lint weight plant^{-1} (49.93, 47.32, 45.12 g), seed cotton yield ha^{-1} (3287.4, 3216.9, 3007.8 kg), seed yield ha^{-1} (2128.5, 2068.2, 1921.6 kg) and, lint yield ha^{-1} (1158.9, 1148.7, 1086.2 kg), respectively. Similarly, the highest values for quality related traits such as GOT (37.10%), staple length (28.95 mm) and seed oil content (25.08 %) were found in crop irrigated five times during the entire crop season; while the six and seven irrigations resulted in relatively lower GOT (36.92, 36.11 %), staple length (28.58, 28.11 %) and oil content (25.03, 24.01 %), respectively. Statisitical analysis further showed that staple length did not vary significantly among seven, six and five irrigations treatments (P>0.05), but GOT and oil content differed significantly. The overall results of this study advocate for five irrigations for Sindh-1 variety to achieve quality crop, because under seven and six irrigations the excessive crop growth had adverse effect on all quality traits investigated in these trials.





ig-1: Plant height (cm)

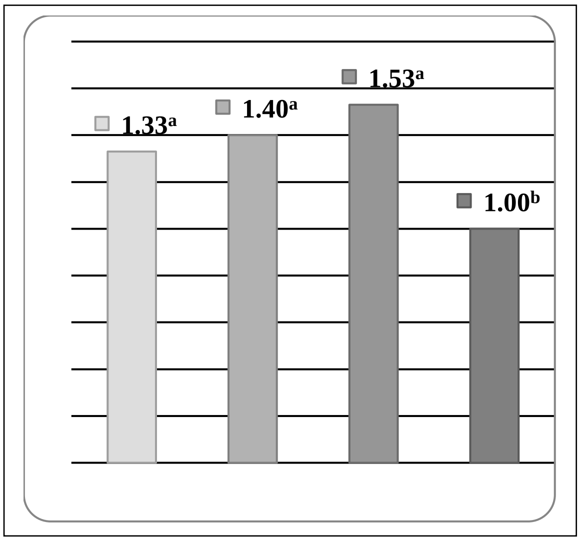


Fig-2: No.of sympodial branches plant-1

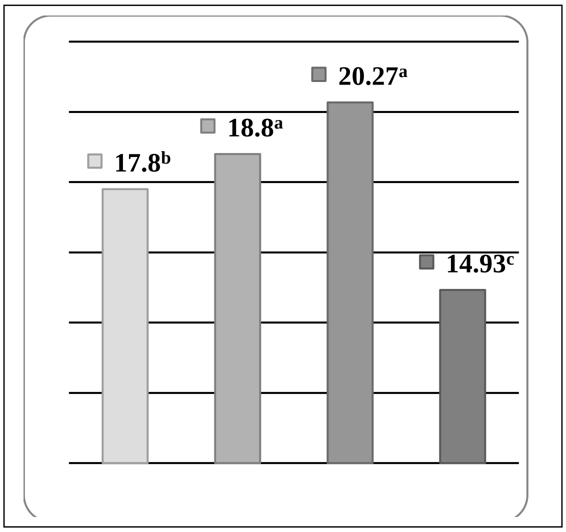


Fig-3: No.of monopodial branches plant-1

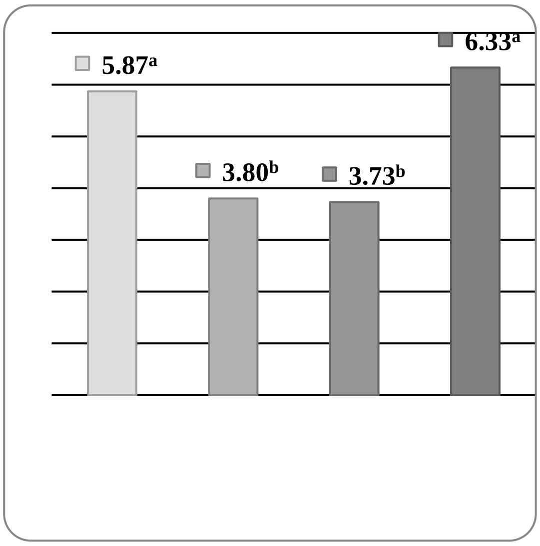


Fig-4: No.of opened bolls plant-1

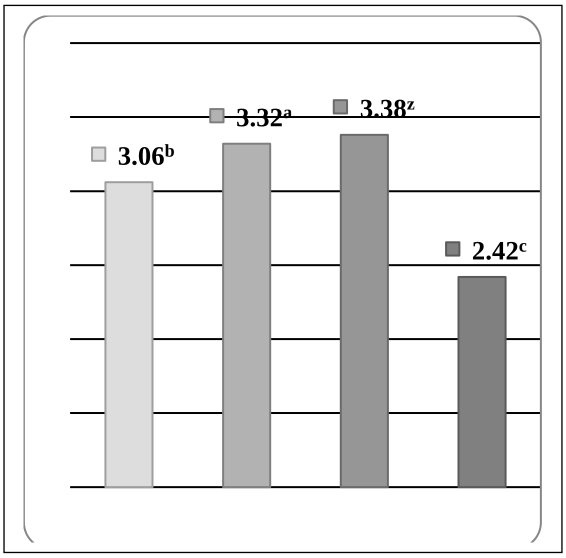


Fig-5: No.of unopened bolls plant-1

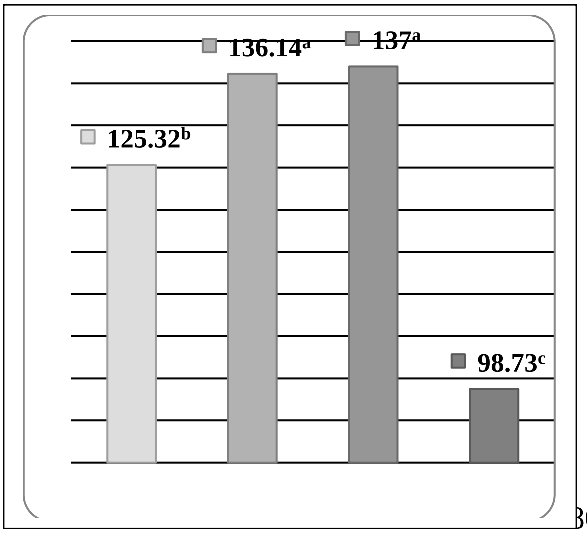


Fig-6: Seed cotton weight boll-1 (g)

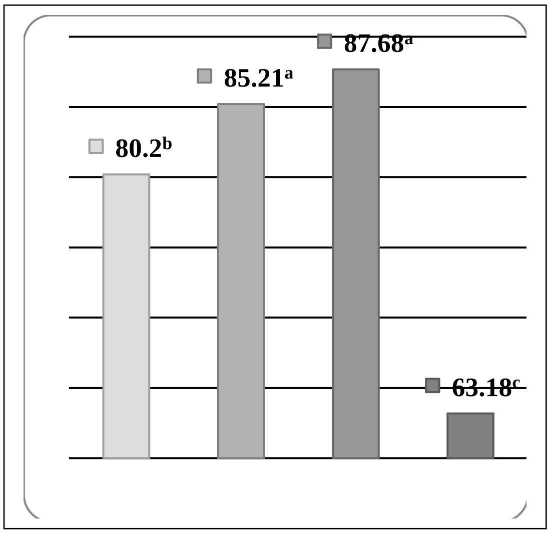


Fig-7: Seed cotton weight plant^{-1} (g)

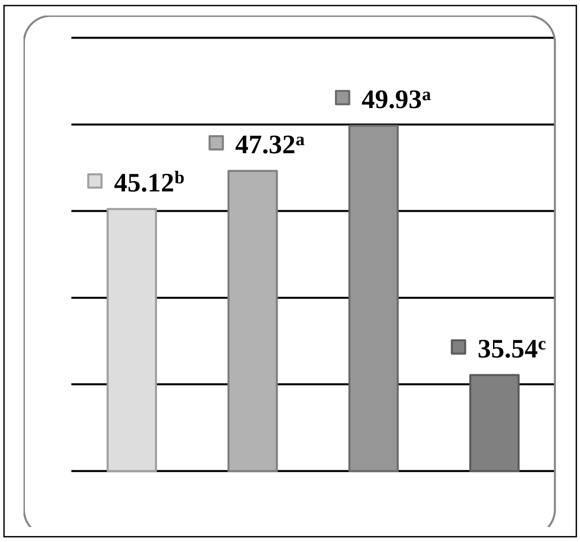


Fig-8: Seed weight plant^{-1} (g)

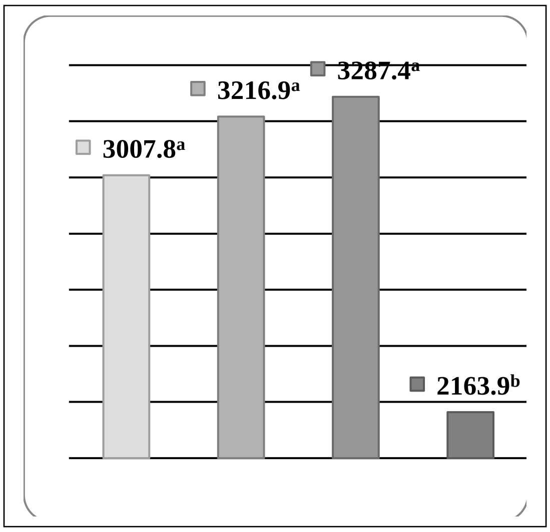


Fig-9: Lint weight plant^{-1} (g)

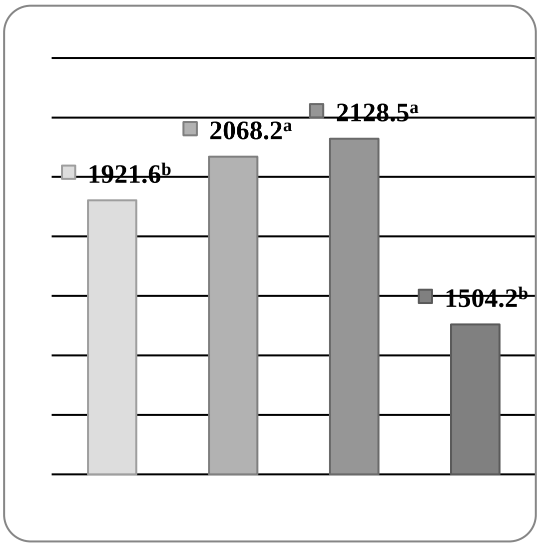


Fig-10: Seed cotton yield ha^{-1} (kg)

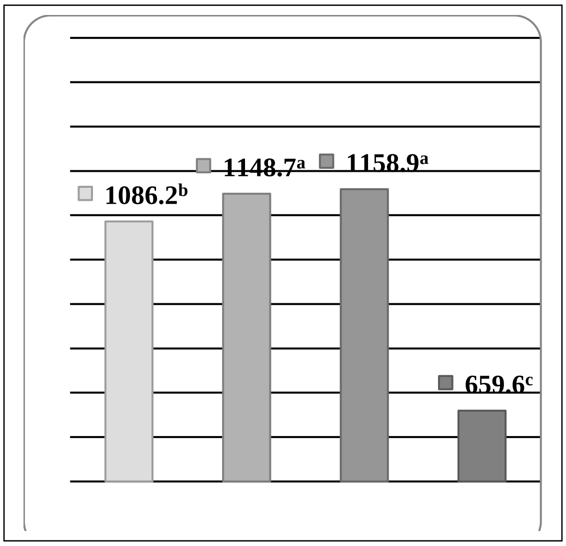


Fig-11: Seed yield ha^{-1} (kg)

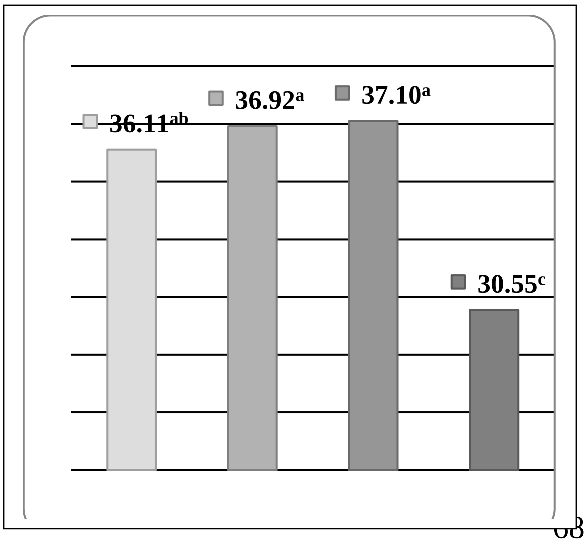


Fig-12: Lint yield ha^{-1} (kg)

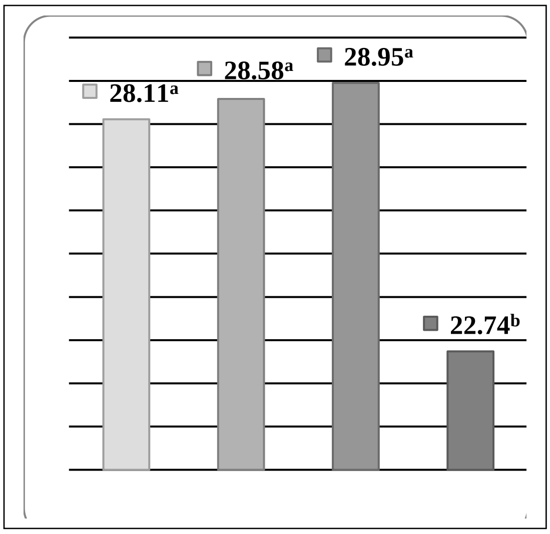


Fig-13: Ginning out-turn (%)

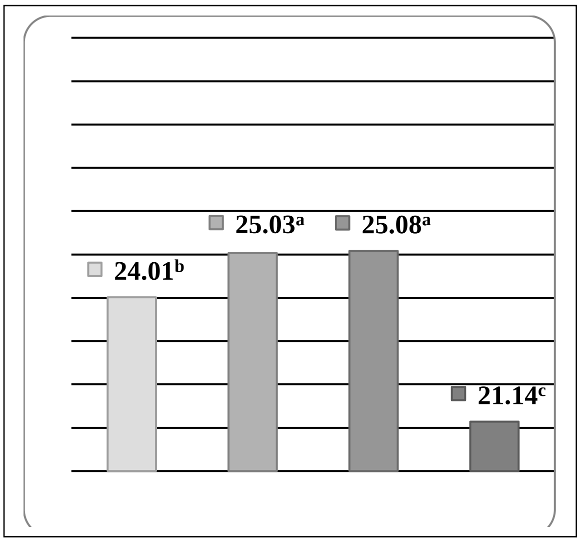


Fig-14: Staple length (mm)

Fig-15: Oil content (%)

Discussion

Pakistan (particularly the Sindh province) is located in the region of acute water shortage; while irrigation management is the most ignored and weaker aspect in the local agriculture system. Of the total available water for agriculture, 65-70 percent is utilized and unfortuanely 30-35 percent water is wasted. Apart from common reasons of water wastage, research on crop specific and variety specific aspects is also seriously lacking. This leads to faulty irrigation that may be either excessive or less than the actual crop requirement and as a result in both cases the effect is poor crop performance. In this research, a newly developed cotton variety Sindh-1 was tested against different irrigation frequencies to optimize its water requirement. Most agronomic indices responded positively to five irrigations than six and seven irrigations.; such as seed cotton weight boll^{-1}, seed cotton weight plant^{-1}, seed weight plant^{-1} , lint weight plant^{-1}, seed cotton yield ha^{-1}, seed yield ha^{-1} and lint yield ha^{-1}. The differences in these traits under 5, 6 and 7 irrigations were non-significant ($P>0.05$). This suggested that six or seven irrigations did not improve or even led to adverse effect on seed cotton, seed and lint yield traits. The apparent reason for such adverse effects is excessive soil moisture due to high irrigation frequency that resulted in prolonged and excessive plant growth. Under these circumstances, number of opened bolls decreased and an increase in unopened bolls was observed. Consequently, the agronomic performance as well as quality traits were significantly influenced. Previously, it has been shown that cotton varieties with an enhanced water use efficiency are highly advantageous under deficit irrigation (Joao et al., 2016). The frequency of irrigation to cotton should be based on environmental conditions including precipitation and a well managed irrigation could lead to improved water use efficiency (Garcia et al. 2010). The existing literature suggests that most of the agronomic traits of cotton including plant height, seed yield and oil content are significantly influenced by different irrigation frequencies (Aziz and Soomro, 2001). Sattar et al. (2017) and Ahmad et al. (2021) reported that locally developed cotton varieties showed extended growth when watered with high frequency and as a result, the boll opening was reduced and plant height was increased. Besides, cotton irrigated systematically improved timely opening of bolls and almost all the bolls were opened upto the harvesting season.

The study further showed that higher values for quality traits such as GOT (37.10%), staple length (28.95 mm) and seed oil content (25.08 %) were found in crop irrigated five times during the entire crop season; while the six and seven irrigations caused relatively lower values for these quality traits. Staple length did not show significant difference for seven, six and five irrigations ($P>0.05$), but GOT and oil content differed significantly ($P<0.05$). The results advocate for five irrigations for Sindh-1 variety to achieve quality crop, because under seven and six irrigations the excessive crop growth had adverse effect on all the investigated quality traits. The results of the present research are in in line with those of many past researchers. For instance, Pak-SCMS (2017) argued that crop varieties may have varied irrigation requirement; and excessive use of irrigation would not improve yield or lint quality but might be uneconomical due to additional water use without parallel improvement in crop yield and quality. Zhang et al. (1997); Dagdelen et al. (2009) and Loka et al. (2011) concluded that there is a need to manage irrigation frequency according to the climatic conditions, varieties and growth stages to maximize yield and quality of cotton and impacts of irrigation. Under the decreasing water resources, improved water use efficiency by better water management practices can serve the purpose and can enhance cotton yields economically (Howell, 2001). The water use efficiency can be improved by applying water saving techniques such as application of water according to the crop need considering the soil moisture, precipitation forecast, interval between each irrigation and the variety (Monem et al., 2001). Vories et al. (2007) emphasized that cotton varieties may require different amounts of irrigation water; as appropriate scheduling enhanced water use efficiency (Joao et al. 2016). This study suggests that water stress, either deficit or excessiveness of water used; both are equally harmful for cotton. Rehman et al. (2019) suggested that variety specific production technologies would be more economical and beneficial for the cotton growers. Luo et al. (2020) also proposed proper modeling to optimize irrigation scheduling in cotton. Likewise, García et al. (2020) emphasized irrigation scheduling based modelling to improve water use efficiency in cotton; while Kouser et al. (2019) are of the view that swift changes in climate demand frequent testing of cotton varieties for optimizing their water requirements.

Conclusions

It can be inferred from the findings of this study that reducing the frequency of irrigations in an irrigation schedule from seven or six to five irrigations for cotton crop can not only save water but also improve various agronomic traits including yield and quality of of Sindh-1 cotton variety. For instance, both cotton seed and lint yields were higher under five irrigations schedulen than six or seven irrigations. The reason could be that an irrigation schedule comprising only five irrigations can fulfill the water requirements of Sindh-1 variety and thus the extra irrigation did not further improve cotton crop performance traits rather exhibited a negative impact of several traits. Thus the existing irrigation water recommendation (6-7 irrigations) is uneconomical, particularly for cotton variety Sindh-1 By exploiting these findings, the growers can save a considerable amount of water which can be utilized to raise other crops or to bring additional area under cotton cultivation and to cope with the current scenario of water shortage. Considering the rapidly decreasing irrigation water resource all around the world, it is imperative to develop new varieties that have minimum water requirements and at par yield with the existing genotypes if not higher.

References

Abdel-Malak, K.K.I. 2005. The proper irrigation intervals for vegetative and fruiting stages of cotton cultivar Giza 83. Egyptian Journal of Agricultural Research. 76, (2) : 765-772.

Ahmad, H.S., M. Imran, F. Ahmad, S. Rukh, R.M. Ikram, H.M. Rafique, Z. Iqbal, A.A. Alsahli, M.N. Alyemeni and S. Ali. 2021. Improving Water Use Efficiency through Reduced Irrigation for Sustainable Cotton Production. Sustainability, 13 (4044) : 1-12.

Aujla, M.S. H.S. Thind and G.S. Butter. 2005. Cotton yield and water use efficiency at various levels of water and N through drip irrigation under two methods of planting. Agric. Water Manag. 71 : 167-179.

Aziz, A.K. and A.G. Soomro. 2001. Effect of water stress on the growth, yield and oil content of sunflower. Pak. J. Agric. Sci., 38: 1-2.

Bhattarai, S.P. 2005. The physiology of water use efficiency of crops subjected to subsurface drip irrigation, oxygation and salinity in a heavy clay soil. Ph.D. Thesis, School of Biol. Env. Sci., Faculty of Arts, Health & Sci., Central Queensland Univ. Rockhampton, QLD 4702, Australia.

Dawn, 2012. Sindh cotton crop estimates. The Dawn. 3 December 2012. Retrieved 13 November, 2015.

Economic Survey of Pakistan 2020-21: Cotton: Finance division, Economic Advisor’s wing, Government of Pakistan, Islamabad, Pp. 19.

English, M.J., K.H. Solomon and G.A. Homan. 2002. A paradigm shift in irrigation management. J. Irrig. Drain. Eng., 128 : 267–277.

Garcia, A.G., T. Persson, L.C. Guerra and G. Hoogenboom. 2010. Response of soybean genotypes to different irrigation regimes in a humid region of the southeastern USA. Agricultural Water Management, 97 (7) : 981-987.

GoP, 2019. Cotton: Pakistan Economic Survey 2019-20, Finance division, Economic Advisor’s wing, Islamabad, Pp. 19.

Goyne, P..J. and G.T. McIntyre. 2001. Improving on farm irrigation water use efficiency in the Queensland cotton and grain industries. A project of QDPI, Agency for Food and Fiber Sciences, Farming System Institute and Australian Cotton CRC.

Harris, G. 2005. Irrigation water balance scheduling. AFFS Farming Systems, DPI and Staff of Australian Cotton Cooperative Research Centre, Pp. 1-5.

Howell, T.A. 2001. Enhancing water use efficiency in irrigated agriculture. Agron. J. 93:281–289.

Howell, T.A., S.R. Evett, J.A. Tolk and A.D. Schneider. 2004. Evapotranspiration of full deficit irrigated, and dryland cotton on the northern Texas high plains. J. Irrig. Drain. Eng. 130:277–285.

Jalota, S.K., A. Sood, G.B.S. Chahal and B.U. Choudhury. 2006. Crop water productivity of cotton (Gossypium hirsutumL.) wheat (Triticum aestivumL.) system as influenced by deficit irrigation, soil texture and precipitation. Agric. Water Manag., 84 (1-2): 137-146.

Joao, H.Z., Z.N. Brandão, V. Sofiatti, J.R.C. Bezerra and J.C. Medeiros. 2016. Irrigation and nitrogen effects on seed cotton yield, water productivity and yield response factor in semi-arid environment. Australian Journal of Crop Science, AJCS 10(1):118-126.

Khan, M.M., A.R. Khilji and S.A. Taran. 2011. Effects of Row Spacing on the Growth and Yield of Sunflower Varieties. LAP Lambert Academic Publishing Co. Pp. 88.

Kouser, S., D.J. Spielman and M. Qaim (2019). Transgenic cotton and farmers' health in Pakistan. PLoS ONE, 14(10):1-19.

Latif, M., S.S. Haider and M.U. Rashid. 2016. Adoption of high efficiency irrigation systems to overcome scarcity of irrigation water in Pakistan. Proc. Pak. Acad. Sci., 53: 243–252.

Loka, D. A., D. Oosterhuis and G. L. Ritchie. 2011. Water-deficit stress in cotton. In: Oosterhuis, D. M. (Ed.). Stress Physiology in Cotton. Cordova: The Cotton Foundation, Chapter 3, Pp. 37-72.

Luo, H., F. Lynch and P Milory. 2020. One-time fertilization at first flowering improves lint yield and dry matter partitioning in late planted short-season cotton. J. Integr. Agr., 18 (2) : 112-220.

Maharana, L., P.P. Dash and K.N.Krishnakumar. 2011. A comparative assessment of BTand non-BTcotton cultivation on farmers livelihood in Andhra Pradesh. J. B io. Sci. Res., 2(2):99-111.

Monem, A., M. A. S., H.E. Khalifa, M. Beider, I.A. El-Ghandour and Y.G.M. Galal. 2001. Using biofertilizers for maize production: response and economic return under different irrigation treatments. Journal of Sustainable Agriculture, 19 (2) : 41-48.

Pak-SCMS. 2017. Pakistan Satellite Based Crop Monitoring System. Bullettin, 6 78:1-26.

PCPA, 2015. Pakistan Cotton and Products Annual. 2015. Global Agricultural Information Network (GAIN). 1 April 2015. Retrieved 13 November 2015.

Rehman, A., L. Jingdong, A.A. Chandio, I. Hussain, S.A. Wagan and Q.U.A. Memon. 2019. Economic perspectives of cotton crop in Pakistan: A time series analysis (1970–2015) (Part 1). J. Saudi Soc. Agri. Sci., 18 : 49–54.

Sattar, M., M.E. Safdar, N. Iqbal, S. Hussain, M.Q. Waqar, M.A. Ali, A. Ali, M.A. Ali and M.A. Javed. 2017. Timing of nitrogen fertilizer application influences on seed cotton yield. Int. J. Adv. Sci. & Res., 2 (1) : 06-09.

Schofield, A. and S. Haigh. 2017. Disturbed Soil Properties and Geotechnical Design (Book), 2nd ed. ICE Virtual Lib: https://www.icevirtuallibrary.com/isbn/9780727761552

Shuli, F., A.H. Jarwar, X. Wang, L. Wang and Q. Ma. 2018. Overview of the cotton in Pakistan and its future prospects. Pakistan Journal of Agricultural Research, 31(4): 396-407.

Sial, K.B., A.D. Kalhoro, M.Z. Ahsan, M.S. Mojidano, A.W. Soomro, R.Q. Hashmi and A. Keerio. 2014. Performance of different upland cotton varieties under the climatic condition of central zone of Sindh. American-Eurasian J. Agric. Environ. Sci. 14: 1447–1449.

Statista, 2018. Cotton production by country worldwide in 2017/2018 (000 metric tons).https://www.statista.com/statistics/263055/cotton-production-worldwide-by-top-countries.

Vories, E.D., R. Hogan, P.L. Tacker, R.E. Glover and S.W. Lancaster. 2007. Estimating the impact of delaying irrigation for Midsouth cotton on clay soil. Transactions of the ASABE, 50(3): 929-937.

Xi-ping, D., L. Shan, H.Zhang and N.C. Turner. 2004. Improving agricultural water use efficiency in arid and semiarid areas of China. New Directions for a Diverse Planet. Proc. 4th International Crop Sci. Conf. Brisbane, Australia.

Zhang, C., J. Sun, J. Chang, X. Huo, C.Y. Zhang, J.K. Sun, J.N. Chang and X.C. Huo. 1997. An analysis of climatic factors favouring a stable yield increase in cotton mulched with double plastic films in the irrigated areas in East Shaanxi. China Cottons, 23 (6) : 11.