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Research Article

Collective effects of irrigation and nutrients on agronomic performance of upland cotton (*Gossypium hirsutum* L.)

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Abstract

Cotton is regarded as backbone of Pakistan economy; as textile industry entirely dependent on cotton for raw material; while cotton seed is principal source of edible oil production contributing around 80% to the domestically produced total edible oil. In enhancing crop yields and fiber quality, optimum use of NPK fertilizers and irrigation frequency is critical; while interactive effect of these two major factors on cotton is not fully understood. Therefore, this research was conducted to examine the interactive effect of NPK fertilizers and irrigation frequency on cotton growth, development and yield. The NPK treatments included: 124-62-62 kg ha^{-1} (10% beyond recommendation); 112-56-56 kg ha^{-1} (recommended) and 100-50-50 kg ha^{-1} (10% less than recommendation); while tested irrigation frequencies included: 7 irrigations (30, 45, 60, 75, 90, 105, 120 DAS); 6 irrigations (30, 50, 70, 90, 110, 130 DAS [existing recommendation] and 5 irrigations (30, 55, 80, 105, 130 DAS). The interaction study showed that growth and yield contributing traits were optimally influenced in positive direction under the interactive effect of 124-62-62 kg ha^{-1} NPK × 5 irrigations. The seed cotton yield ha^{-1} was slightly higher (3482 kg) in crop fertilized with 124-62-62 kg ha^{-1} NPK × 7 irrigations as compared to seed cotton yield of 3456.50 and 3448 kg ha^{-1} realized in the interactive effect of NPK at 124-62-62 kg ha^{-1} × 6 irrigations and NPK at 124-62-62 kg ha^{-1} × 5 irrigations; while the least seed cotton yield (2691 kg ha^{-1}) was obtained in treatment interaction of 100-50-50 kg ha^{-1} × 7 irrigations. However, 7, 6 and 5 irrigations regardless of rate of NPK application showed similarity ($P>0.05$) in agronomic performance of cotton; while NPK level of 124-62-62 kg ha^{-1} (10% higher than existing recommendation) showed economically viable results. Hence, the treatment based on interaction of NPK @124-62-62 kg ha^{-1} × 5 irrigations (at 30, 55, 80, 105, 130 DAS) could be practically suggestible for cotton growers, particularly while growing newly evolved variety Sindh-1.

Keywords: Cotton, variety Sindh-1, Interactive effect NPK, Irrigation frequency, Seed, Lint and yield

Introduction

Cotton (*Gossypium hirsutum* L.) is largely cultivated in Pakistan for being highly lucrative crop for the production of fiber and has the potential to contribute to long-term economic prosperity of the country; because a significant portion of land is devoted to its cultivation. Hence, there has always been a lot of interest from the scientific community in studying its different aspects to improve its economic yield and fiber quality [1]. This crop has prime importance, since it is the only source of raw material for the textile industry of Pakistan; makes a sizeable contribution to the world supply of edible oil. According to [2]. Pakistan is fifth largest producer of cotton worldwide after China (5879 tons), India (5334 tons), the United States (3815 tons), and Brazil (2678 tons). The cotton and textiles account for up to 60 percent of total overall exports of Pakistan, making significant economic drivers for the nation by 0.6% contribution to GDP. A significant decrease in area under cotton (6.8%) has been recorded due to shift of cotton area to other crops such as sugarcane, maize, potato and rice (2.079 million ha in 2020-21 to 1.937 million ha in 2021-22). Although, the crop was generally cultivated on reduced area this year, but tremendous increase in yields compensated well the challenging adverse effect of decreased area under cotton cultivation this year. The growers enjoyed most favorable weather this year for cotton, coupled with more consistent supply of inputs, improved crop management, and higher lint prices in local and international markets that encouraged the increased cotton production [3].

Cotton growers in Pakistan have adopted *Bt* cotton swiftly and more than 95 percent of the farming communities preferably cultivate *Bt* cotton. In Punjab and Sindh provinces a total of 24 cotton varieties have been approved which also included 12 *Bt* varieties [4]. On the other hand, in Sindh province, local cotton varieties are also cultivated; however, their share in overall acreage under cotton is continuously decreasing due to the increasing demand for *Bt* cotton varieties [5]. According to Fatima *et al*. [6], non-*Bt* cotton has been swiftly replaced with *Bt* varieties in the country. The possibility of switching to imported *Bt* cotton seed is being evaluated regardless of the current condition of the ecosystem in which it is cultivated. The introduction of *Bt* cotton was largely accepted by the farmers that it has ability of resistance to most destructive insect pests. Despite the fact that there were numerous discussions concerning the benefits and drawbacks of cultivating *Bt* cotton, its use became widespread. The vast majority of farmers have not followed to the requisite agricultural production regime that is crucial to maintaining the success of *Bt* cotton technology, and as a result, its adoption has been uneven and unsuited [7]. Nevertheless, because the seed of numerous unrecognized and unapproved cotton varieties is available in the seed market, it has been difficult for farmers and researchers to realize the benefits of *Bt* cotton [8]. Cotton output all over the world has been limited as a result of issues such as varietal infection, nutritional imbalance, and an inadequate supply of irrigation water [9].

The soils in Pakistan being used for agriculture purposes are crucially N deficient, followed by alarming soil P-deficiency, and soil K deficiency has also been acknowledged. Such deficiency of major nutrients that are essentially required for achieving higher crop yields [10] needs to be corrected by viable nutritional balance to ensure sustainable higher crop yields [11].

[12] realized maximum seed cotton yields when fertilized with 150-75-75 kg ha^{-1} NPK in India; while in Egypt 90-15-30 kg NPK ha^{-1} were recommended for cotton [13]. The variation in NPK requirement is associated with the soil health, soil management and

cropping intensity. In Sindh (Pakistan), the application of 150-50 NP kg ha^{-1} were suggested by [14] to achieve desired agronomic performance of cotton.

The optimistic rate of nutrients needs to have specific knowledge of cotton varieties for their nutrient requirements considering their nutrient uptake and soil/plant analysis. Hence, nutrient requirement and uptakes can only be determined by knowing the requirement of a cotton variety at its various phonological stages to develop adoptable nutritional management approach [15-17]. The introduction of new cotton varieties showed 20-24% increase in NPK use efficiency [18, 19] as *Bt* varieties were found more responsive to fertilizers and irrigation water coupled with resistance against pests and diseases [20, 21]; while the cotton varieties evolved locally in the past have been replaced by new varieties [22]. Therefore, existing nutrient recommendations may not represent the actual nutritional requirement of recently developed cotton varieties and need to be optimized [23, 24].

Stable soil moisture is essential to the production of a successful cotton crop; yet, irrigated farms are having trouble locating sources of water that are within their price range [25, 26]. Despite the fact that Pakistan is located in an area with a limited supply of water, the agricultural sector continues to serve as the cornerstone of the national economy. The country has its most acute water shortages during monsoon/ post-monsoon seasons and throughout winter months. Hence, it is imperative to adopt innovative water saving methods as developed and adopted in China [27]. In cotton-growing regions of Pakistan, there is a severe paucity of drought-resistant cotton varieties and lack of effective water management; despite the fact that using varieties with drought resistance can highly be effective to enhance water use efficiency [28-30]. According to [31, 32], achieving the desired economic yields in cotton under water deficit situations requires both an efficient irrigation system and drought resistant cultivars; and these factors are crucial to reaching the desirable crop yields [33]. For estimating the amount of water in the soil, this technique uses a more comprehensive view of the root zone of the crop [34]. If irrigation is skipped throughout the vegetative development phases, the crop might end up producing less crop yields. On the other hand, careful irrigation management has the ability to improve the amount of water that is utilized productively for irrigation [35]. Understanding the water regimes that increase crop yields and improve irrigation efficiency is essential [36]. When farmers irrigate their crops using the ineffective fixed-interval approach, they frequently apply an excessive amount of water to their crops. Yet, the success of the crop can be negatively impacted by both an abundance and a shortage of water [37]. Therefore, optimizing the use of NPK fertilizers and irrigation frequency is critical to achieve high cotton yield. However, the interactive effect of NPK fertilizers and irrigation frequency on cotton growth and yield is not fully understood. This research aims to investigate the interactive effect of NPK fertilizers and irrigation frequency on cotton growth, development, and yield. The findings of this study will contribute to the development of sustainable cotton production practices, enhance the efficiency of NPK fertilizer and water use, and improve the cotton yield and quality.

Materials and Methods

This research was carried out in the research premises of the Agricultural Research Center (ARC) Tandojam, Sindh, which is situated at 25º26'O N latitude and 68º32'O E longitude. The experiment was carried out in 2018 during the Kharif season, and its purpose was to investigate the interacting effect that NPK fertilizers and irrigation frequency on the

growth and production of cotton. In order to establish a fine seedbed on the experimental land, the preparation process began with two dry plowings, then continued with heavy soaking, precise levelling, and cultivator ploughs. For the purpose of the experiment, cotton variety Sindh-1 was utilized, and the seeds were planted using the drilling method in RCBD (factorial) with three replicates. In accordance with the procedures outlined in the treatment plan, the NPK fertilizers were administered at varying concentrations, and the crop was watered in the appropriate manner. Weeds, insect pests, and diseases were all managed; and effective plant protection measures were implemented. The first picking was carried out at a time when fifty percent of the bolls had opened, and successive harvests were carried out at intervals of fifteen to twenty days. This study sheds important light on how frequently cotton should be irrigated and how much N, P, and K fertilizers should be used for optimum crop development and output.

The data on agronomic characteristics of cotton, such as the height of plants, number of monopoial and sympodial branches, the number of bolls, and the proportion of opened to unopened bolls in a sample of five plants, were recorded visually. The height of the plants was measured with a measuring tape that was accurate to the nearest 0.01 centimeter. In order to calculate the average seed-cotton weight, seed weight, and lint weight, twenty bolls were taken from each plot and placed on an automatic top loading scale on the basis of five plants selected at random from each sub-plot. This allowed for the calculation of the average seed-cotton weight, seed weight, and lint plant^{-1}. The total seed cotton yield was calculated by weighing and averaging the seed cotton gathered from three replicates of a particular treatment, and the yield per hectare was calculated using a process very similar to that used for the total seed cotton yield. First, the lint and the seed were weighed independently. Then, the weight of the lint and the weight of seed were taken together.

Statistix 8.1 was used for statistical analysis of the data gathered about the interactive effect of NPK fertilizers and irrigation frequency on cotton growth and yield **[38]**. In order to find out if there were any significant difference between the treatments, the data were evaluated thoroughly. The LSD test was used to make any required comparisons of the efficacy of different treatments. By the use of statistical analysis, we were able to get insight into the appropriate use of NPK fertilizers, irrigation frequency, and cotton growth to maximize cotton production and quality.

Results and Discussion

Plant height

The data in (Fig. 1) illustrated that the plants grew 88.14, 82.44 and 80.10 cm tall when irrigated 7, 6 and 5 times; while the average plant height in crop fertilized with NPK @124-62-62, 112-56-56 and 100-50-50 kg ha^{-1} was 88.06, 83.61 and 79.01 cm, respectively. The interactive effect of NPK and irrigation levels indicated that on average, the cotton plants grew maximally taller (97.76 cm) when fertilized with 124-62-62 kg ha^{-1} NPK level and given seven irrigations; followed by 87.80 cm and 84.75 cm plant height recorded under the interactive effect of NPK at 112-56-56 kg ha^{-1} × 7 irrigations and 124-62-62 kg ha^{-1} NPK × 6 irrigations, respectively.

Sympodia plant^{-1}

The sympodia plant^{-1} remained 12.22, 11.83 and 11.39 under 7, 6 and 5 irrigations; while average number of sympodia plant^{-1} were 14.50, 11.34 and 9.61 under NPK levels of 124-62-62, 112-56-56 and 100-50-50 kg ha^{-1}, respectively (Fig. 2). The treatments interactive effect (NPK × irrigation levels) depicted that on average, the maximum number of sympodia (15.00 plant^{-1}) were observed in plots fertilized with lowest NPK

level of 124-62-62 kg ha^{-1} and given 7 irrigations; closely followed by 14.50 cm and 14.00 sympodia plant^{-1}detected in the interactive effect of 124-62-62 kg ha^{-1} NPK × 6 irrigations and NPK at 124-62-62 kg ha^{-1}×5 irrigations, respectively. This indicates that five irrigations would be enough to economically maximize the value of this trait.

Monopodia plant^{-1}

The number of monopodia (Fig. 3) in crop irrigated 7, 6 and 5 times was 1.60, 1.51 and 1.28 plant^{-1}; the crop fertilized with NPK fertilizer levels of 124-62-62, 112-56-56 and 100-50-50 kg ha^{-1} produced average monopodia up to 1.51, 1.61 and 1.26 plant^{-1}, respectively. The interactive effect of NPK × irrigation levels portrayed that on average, the maximum number of monopodia (1.79 plant^{-1}) were recorded under NPK level of 112-56-56 kg ha^{-1} and given 7 irrigations; followed by 1.55 monopodia plant^{-1} detected in the interactive effect of NPK at 112-56-56 kg ha^{-1} × 5 irrigations, respectively.

Opened bolls plant^{-1}

The average opened bolls plant^{-1} in cotton irrigated 7, 6 and 5 times were 17.13, 17.16 and 16.46 plant^{-1}; whereas the cotton supplied with NPK fertilizer at the rates of 124-62-62, 112-56-56 and 100-50-50 kg ha^{-1} resulted in 18.68, 16.73 and 16.33 opened bolls plant^{-1}, respectively (Fig. 4). The treatment interaction of NPK × irrigation represents that averagely, the highest number of opened bolls (18.88 plant^{-1}) were found in crop given NPK at the rate of 124-62-62 kg ha^{-1} and given 6 irrigations; closely followed by 18.71 and 18.75 opened bolls plant^{-1} detected in the interactive effect of NPK at 124-62-62 kg ha^{-1} × 7 irrigations and 124-62-62 kg ha^{-1} × 5 irrigations, respectively. However, the minimum opened bolls plant^{-1}were resulted by the treatment interaction of 100-50-50 kg ha^{-1}×5 irrigations, respectively. It was noted that the number of opened bolls were almost similar in crop given 5, 6 and 7 irrigations.

Unopened bolls plant^{-1}

The cotton plantation given 7, 6 and 5 irrigations averagely resulted in 3.97, 3.69 and 3.42 plant^{-1}; whereas the crop fertilized with NPK levels of 124-62-62, 112-56-56 and 100-50-50 kg ha^{-1} averagely resulted in 4.63, 3.46 and 3.00 unopened bolls plant^{-1}, respectively (Fig. 5). The interactive effect of treatments showed that number of un-opened bolls was highest (5.00 and 5.08 plant^{-1}) in crop receiving NPK at 124-62-62 kg ha^{-1} and 7 irrigations and 124-62-62 kg ha^{-1} and 6 irrigations; followed by 4.41 un-opened bolls plant^{-1}found in interaction of NPK at 112-56-56 kg ha^{-1} × 7 irrigations; while the lowest un-opened bolls plant^{-1} (2.50) were equally counted in interaction of 112-56-56 kg ha^{-1} × 5 irrigations and NPK at 100-50-50 kg ha^{-1} × 7 irrigations, respectively.

Seed cotton weight boll^{-1}

The crop irrigated 7, 6 and 5 times averagely produced seed cotton weight of 2.75, 2.67 and 2.69 g boll^{-1}; while the crop enriched with NPK levels of 124-62-62, 112-56-56 and 100-50-50 kg ha^{-1} averagely produced 2.75, 2.88 and 2.48 g seed cotton weight boll^{-1}, respectively (Fig. 6). Interactive effect of NPK×irrigation regimes indicates that on average the seed cotton weight boll^{-1} was highest (3.43 g) in crop fertilized with 112-56-56 kg ha^{-1}NPK × 7 irrigations; followed by 2.84 and 2.84 g seed cotton weight boll^{-1}achieved in the interactive effect of NPK at 124-62-62 kg ha^{-1} × 6 irrigations, and 124-62-62 kg ha^{-1} × 5 irrigations, respectively. However, the least seed cotton weight boll^{-1}(2.27 g) was obtained in the treatment interaction of 100-50-50 kg ha^{-1}×7 irrigations. This suggested that the application of NPK fertilizers at the rate of 124-62-62 kg ha^{-1} × 6 irrigations was more economical to maximize seed cotton weight boll^{-1} over rest of the treatment interactions.

Lint weight boll^{-1}

The cotton crop supplied with 7, 6 and 5 irrigations averagely produced lint weight of

0.92, 0.88 and 0.99g boll^{-1}, while NPK rates of 124-62-62, 112-56-56 and 100-50-50 kg ha^{-1} resulted in average lint weight of 1.11, 0.93 and 0.75 g boll^{-1}, respectively (Fig. 7). Treatments' interaction suggested that 124-62-62 kg ha^{-1} NPK × 5 irrigations resulted in maximum lint weight boll^{-1} of 1.22 g; followed by 1.09 g lint weight boll^{-1} recorded in treatment interaction of 124-62-62 kg ha^{-1} × 7 irrigations. However, the least lint weight boll^{-1} (0.72 g) was recorded in 100-50-50 kg ha^{-1} × 7 irrigations. Five irrigations maximized lint weight boll^{-1} under 124-62-62 kg ha^{-1} NPK fertilization, but NPK level of 124-62-62 kg ha^{-1} remained uneconomical under 7 irrigations.

Seed weight boll^{-1}

The crop given 7, 6 and 5 irrigations averagely produced seed weight of 1.62, 1.80 and 1.87 g boll^{-1} (Fig. 8); while NPK at the rates of 124-62-62, 112-56-56 and 100-50-50 kg ha^{-1} averagely produced seed weight of 1.83, 1.74 and 1.72 g boll^{-1}, respectively. Interactive effect of 124-62-62 kg ha^{-1} NPK × 5 irrigations maximized the seed weight boll^{-1} (2.20 g); followed by 1.90 g seed weight boll^{-1} recorded in treatment interaction of 100-50-50 kg ha^{-1} × 6 irrigations. However, the least seed weight boll^{-1} (1.54 g) was obtained in 100-50-50 kg ha^{-1}×7 irrigations. It is evident from the study that 5 irrigations maximized seed weight boll^{-1} under highest NPK rate of 124-62-62 kg ha^{-1}, but NPK level of 124-62-62 kg ha^{-1} remained uneconomical under 7 irrigations (Fig. 8).

Seed cotton yield ha^{-1}

The crop supplied with 7, 6 and 5 irrigations averagely produced seed cotton yield of 3128.17, 3118.67 and 3116.17 kg ha^{-1}; while under NPK levels of 124-62-62, 112-56-56 and 100-50-50 kg ha^{-1} the crop produced seed cotton yield of 3462.17, 3200.17 and 2700.67 kg ha^{-1}, respectively (Fig. 9). The interaction study showed that seed cotton yield ha^{-1}was relatively higher (3482kg) in crop fertilized with 124-62-62 kg ha^{-1} NPK × 7 irrigations; followed by 3456.50 and 3448 kg ha^{-1} seed cotton yield realized in the interactive effect of NPK at 124-62-62 kg ha^{-1} × 6 irrigations and NPK at 124-62-62 kg ha^{-1} × 5 irrigations; while the least seed cotton yield (2691kg ha^{-1}) was obtained in treatment interaction of 100-50-50 kg ha^{-1} × 7 irrigations.

Lint yield ha^{-1}

The lint yield in cotton under the influence of 7, 6 and 5 irrigations was 1222.64, 1214.66 and 1209.66 kg ha^{-1} on average; while fertilizers (124-62-62, 112-56-56 and 100-50-50 kg ha^{-1} NPK) produced average lint yield of 1367.18, 1247.40 and 1032.38 kg ha^{-1}, respectively (Fig. 10). Treatment interaction comprised of 124-62-62 kg ha^{-1} NPK × 7 irrigations maximized the lint yield (1382.02 kg ha^{-1}); followed by 1364.65 kg lint yield ha^{-1}obtained in the treatment interaction of 124-62-62 kg ha^{-1} NPK × 6 irrigations; while the least lint yield (1030.96 kg ha^{-1}) was realized in the interaction of 100-50-50 kg ha^{-1}× 7 irrigations. It is evident from the results that lint yield obtained under 124-62-62 kg ha^{-1}surpassed the lint yield obtained under recommended dose of NPK fertilizers (112-56-56 kg ha^{-1}) in a significant fashion; which justifies that the existing recommendations for NPK fertilizers (112-56-56 kg ha^{-1}) is outmoded and for achieving higher lint yields, the soil needs to be fertilized with 124-62-62 kg ha^{-1} NPK fertilizers. Moreover, the 7 irrigations caused excessive crop growth and developed increased bolls plant^{-1} but lint yield decreased due to more share wasted in the development of new bolls most of them remained unopened. Hence, 5 irrigations could adequately fulfil the crop requirement for this trait under higher NPK level of 124-62-62 kg ha^{-1}, as the differences in lint yield between 7, 6 and 5 irrigations regardless of NPK rates was non-significant ($P>0.05$).

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Seed yield ha^{-1}

It is apparent from the study results that the seed yield was averagely 1905.52, 1904.01 and 1906.51 kg ha^{-1} under 7, 6 and 5 irrigations; while NPK fertilizers application at the rates of 124-62-62, 112-56-56 and 100-50-50 kg ha^{-1} averagely resulted in seed yield of 2094.99, 1952.76 and 1668.29 kg ha^{-1}, respectively (Fig. 11). The interaction based on highest NPK level of 124-62-62 kg ha^{-1} × 7 irrigations resulted in relatively higher seed yield (2099.98 kg ha^{-1}); closely followed by 2093.13 and 2091.85 kg ha^{-1}seed yield achieved in the interaction of 124-62-62× 5 irrigations and 124-62-62× 6 irrigations, respectively; but the differences among 5, 6 and 7 irrigations for seed yield were non-significant (P>0.05) regardless of NPK rates and years of study. However, the least seed yield (1660.04 kg ha^{-1}) was found in the interaction of 100-50-50 kg ha^{-1} ×7 irrigations. The treatment effect clearly suggested that five irrigations would be adequate to fulfil the crop need for achieving higher seed yield; however, the existing recommendation of 112-56-56 kg ha^{-1} NPK could not prove adequate for the present soil status and needs to be increased; as the seed yield as well as almost all the other traits showed better crop performance under increased NPK level of 124-62-62 kg ha^{-1}. Hence, for achieving desired seed yield in cotton variety Sindh-1, the crop will need 124-62-62 kg ha^{-1} NPK fertilizers under 5 irrigations.

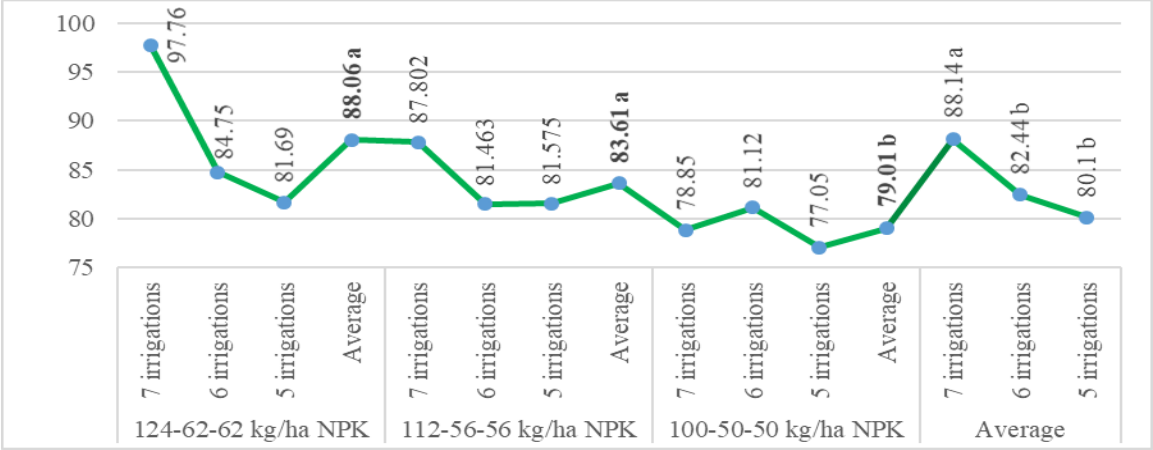

Figure 1: Interactive effect of NPK × irrigation levels on plant height (cm)

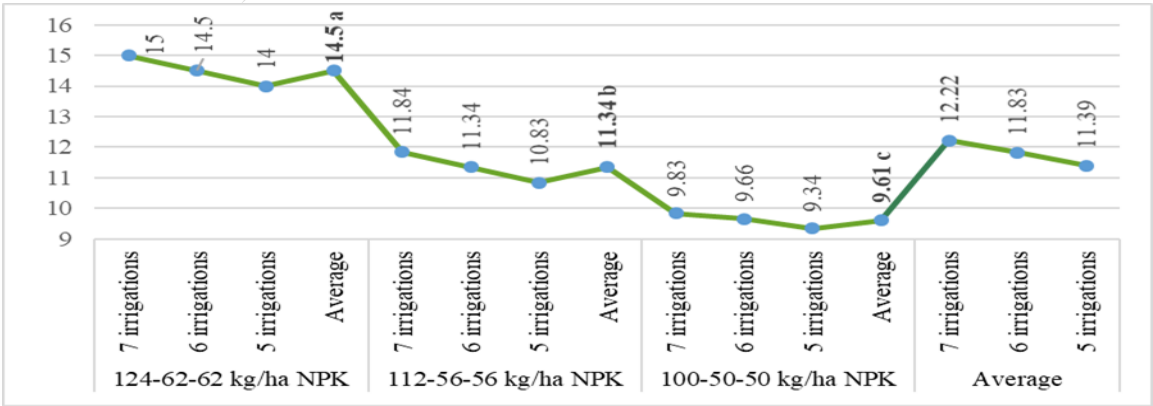

Figure 2: Interactive effect of NPK × irrigation levels on sympodia plant^{-1}

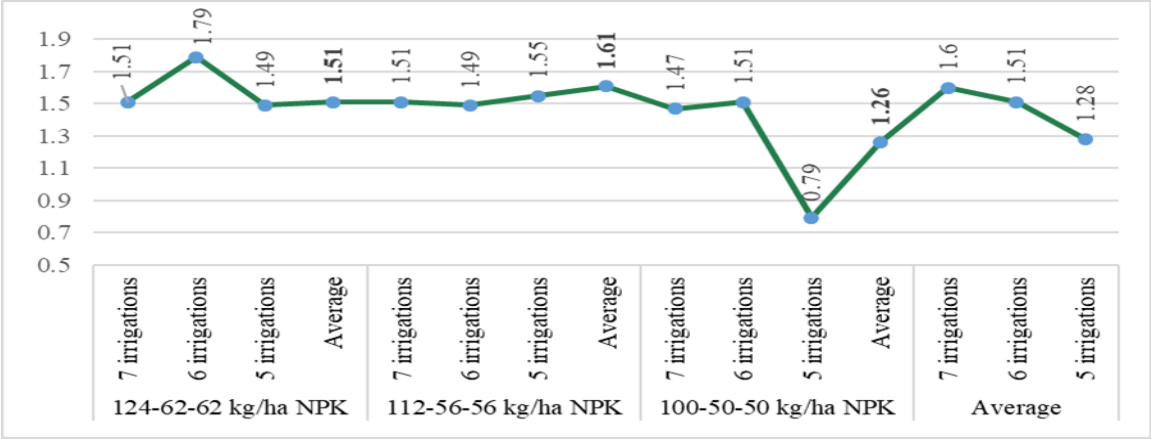

Figure 3: Interactive effect of NPK × irrigation levels on monopodia plant^{-1}

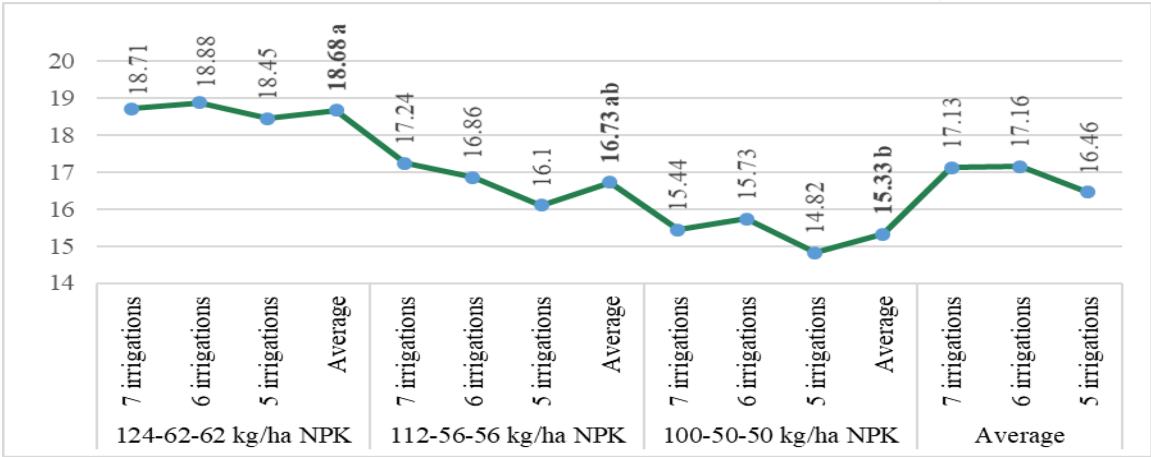

Figure 4: Interactive effect of NPK × irrigation levels on opened bolls plant^{-1}

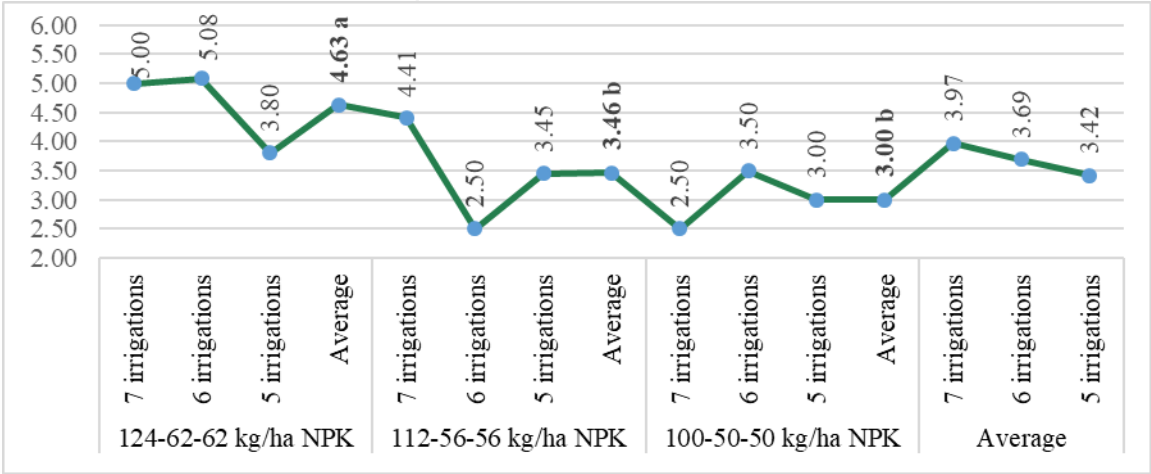

Figure 5: Interactive effect of NPK × irrigation levels on unopened bolls plant^{-1}

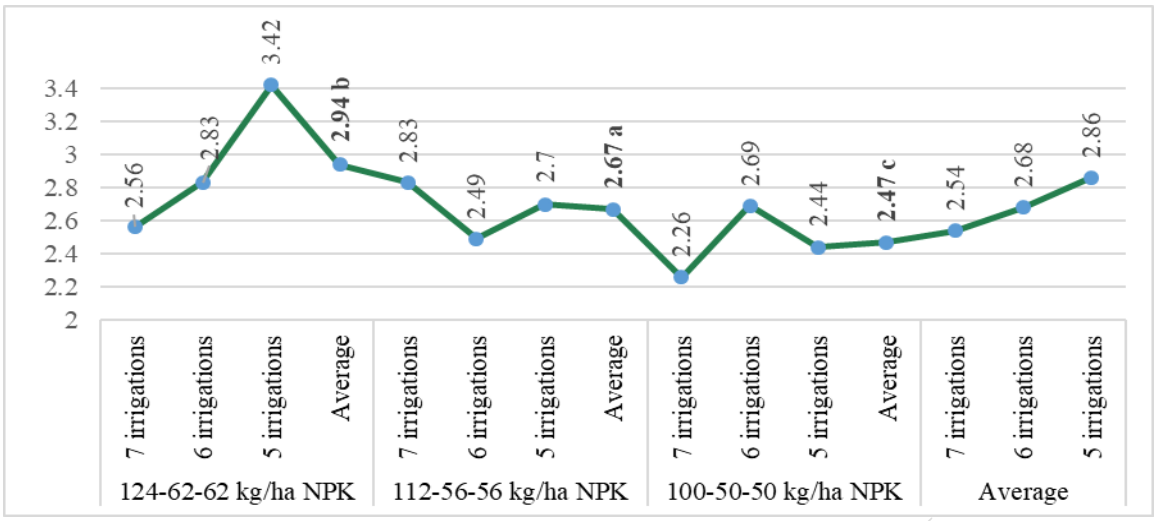

Figure 6: Interactive effect of NPK × irrigation levels on seed cotton weight boll^{-1} (g)

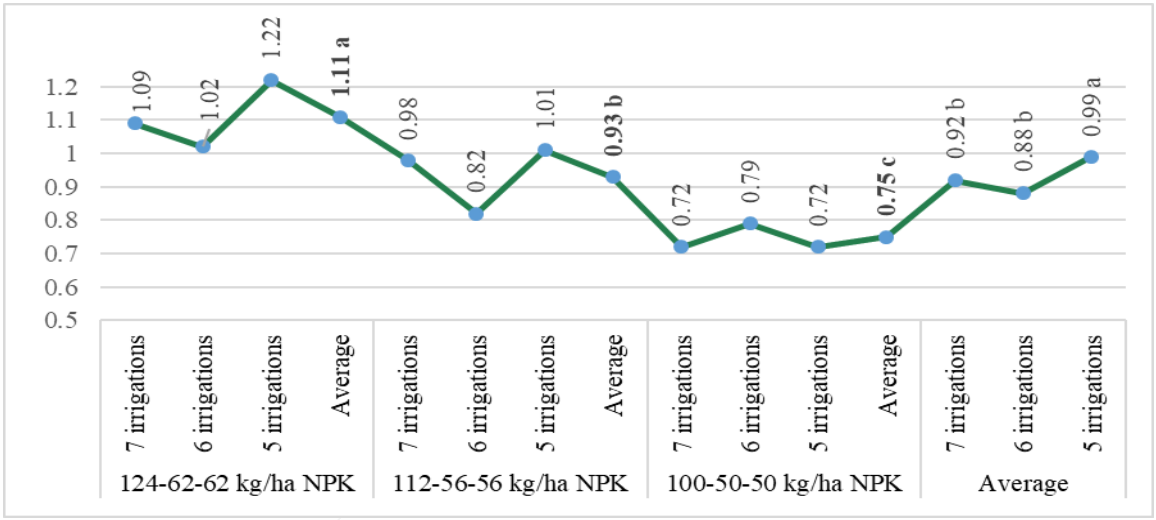

Figure 7: Interactive effect of NPK × irrigation levels on lint weight boll^{-1} (g)

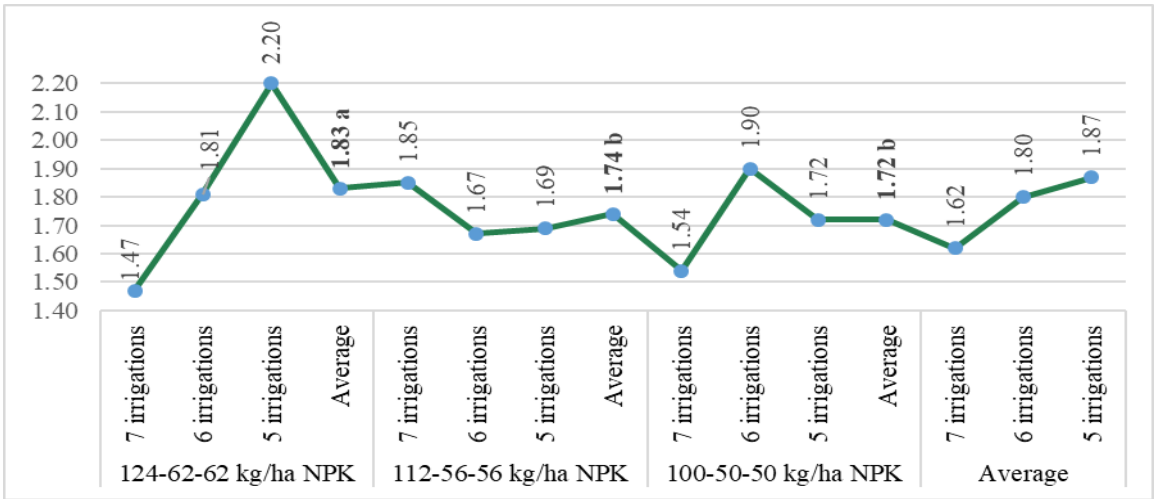

Figure 8: Interactive effect of NPK × irrigation levels on seed weight boll^{-1} (g)

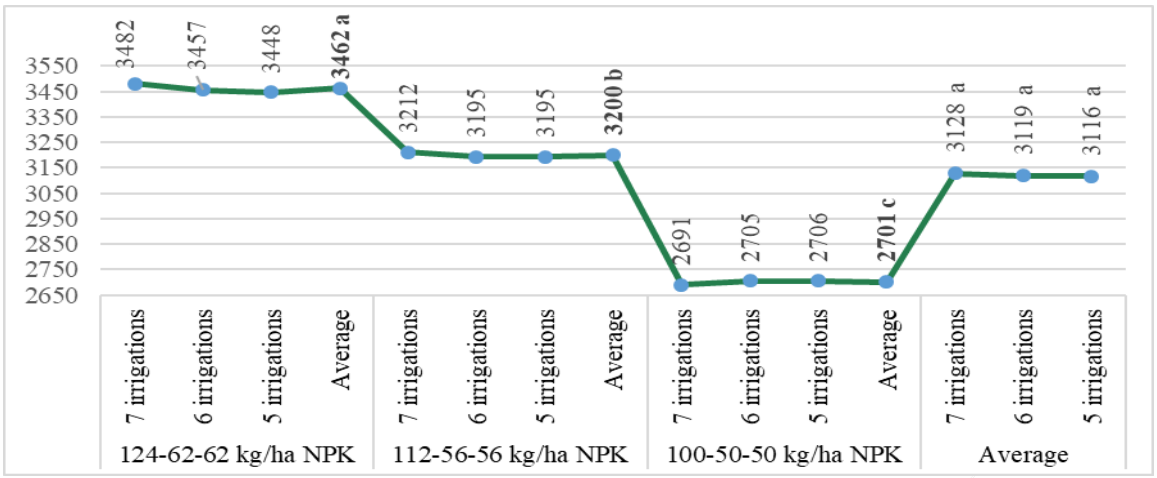

Figure 9: Interactive effect of NPK × irrigation levels on seed cotton yield ha^{-1} (kg)

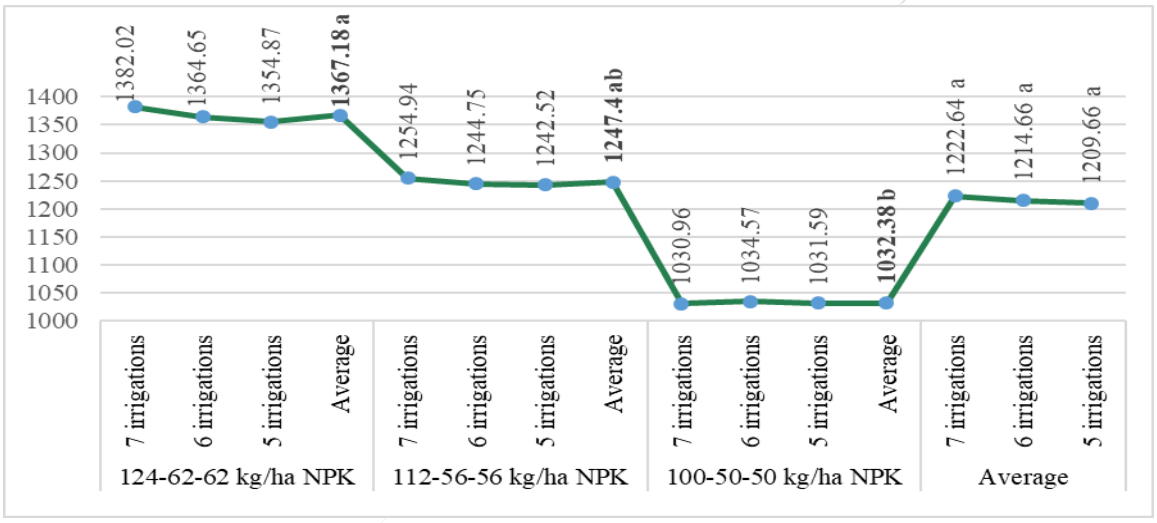

Figure 10: Interactive effect of NPK × irrigation levels on lint yield ha^{-1} (kg)

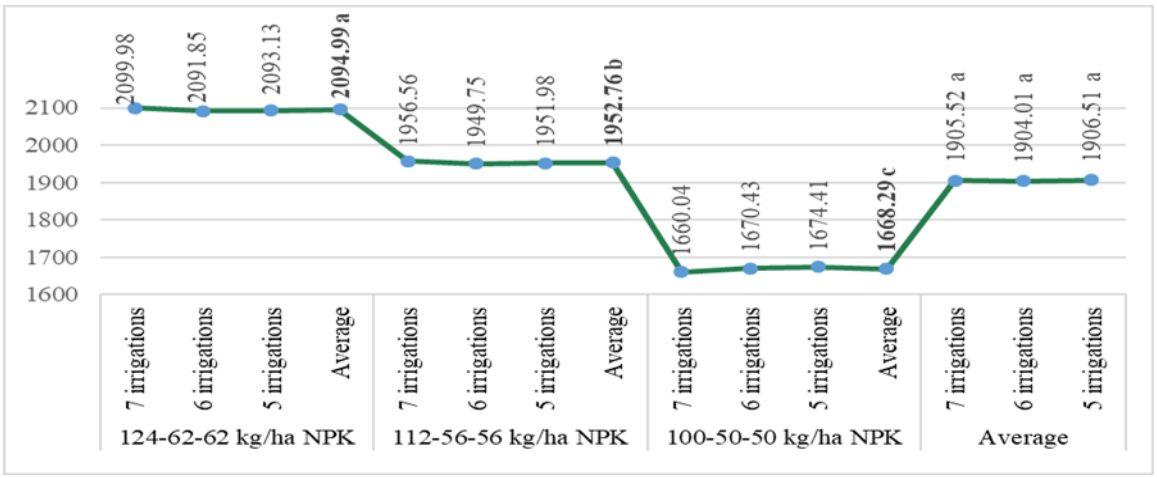

Figure 11: Interactive effect of NPK × irrigation levels on seed yield ha^{-1} (kg)

Discussion

The study acknowledged that recommended dose of NPK fertilizers (112-56-56 kg ha^{-1}) did not show promising performance and NPK @124-62-62 kg ha^{-1} showed highly economic impact on cotton production in relation to growth and yield traits. The study results are endorsed by **[39]** who argued that cotton varieties are cultivated across the country without registration in the local ecological conditions. Thus, variety specific nutrients and irrigation requirement may be assessed. **[40]** reported that with the deteriorating soil fertility status and increasing salinity, the recommendations regarding fertilizers need to be optimized frequently. **[41]** have suggested that locally developed cotton varieties must be examined for their input requirements due to fast changing soil and climatic conditions. The role of NPK in achieving desired crop yields is inevitable **[42]**. Decline in soil fertility is susceptible to sustainability **[43]** and such soil conditions in countries operating with conventional agriculture is devastating **[44]**. There is immediate need to assess the existing fertilizer recommendations and optimize them under frequent climate change to ensure sustainable cotton yields **[45]**. **[46]** emphasized for continuous soil testing for nutrients essentially needed for cotton production for optimization. **[47-49]** suggested that NPK requirement of cotton is mainly associated with the soil type, soil quality and availability of irrigation water. Thus, under such circumstances, the soil NPK requirements may change fast **[50, 51]** argued inter and intra region soil variations and sometimes inter region soil variation is markedly higher than the intra-regional variations. **[52]** concluded that with change in the soil temperature and deteriorating soil nutrient levels, the recommendations for soil applied nutrients needs revision. **[53]** have suggested that the cotton nutrient requirement needs to be linked with new varieties and their nutrient requirement may be assessed time to time, so that under the changing soil and climatic conditions, the nutrient requirements are timely optimized.

The economic viability of growing the cotton variety, particularly the newly developed variety Sindh-1 was also proven by the study; however, this success was contingent on the plant receiving five irrigations. According to the findings, the impacts of six or seven irrigations had a negative impact on the seed cotton yield, as well as the seed and lint yield characteristics that were investigated. It would appear that the prolonged and excessive plant growth that happened as a direct result of the high frequency with which irrigation was applied is the primary factor that led to these unforeseen results. Because of these circumstances, the percentage of opened bolls decreased, while the percentage of unopened bolls increased. This indicates that the bolls are becoming more difficult to open under excessive growth of plants due to high irrigation frequency. As a consequence of this, there was a significant impact on the agronomic performance as well as the quality characteristics. The findings of this study are in agreement with the findings of **[54]** who claimed that cotton should be grown with increased water consumption efficiency that is particularly favorable under deficit irrigation. In order to achieve optimal results, irrigation plans for cotton should take into consideration both the upcoming weather and any other relevant external elements **[55]**. **[56, 57]** showed that locally developed cotton varieties demonstrated tall growing when they were irrigated more frequently. This, in turn, decreased boll opening and increased plant height. In addition, cotton that was constantly watered exhibited much improved boll opening, with virtually all bolls opening in time for harvest; and this was probably a significant advantage.

The interactive effect of NPK and irrigation showed that 124-62-62 kg ha^{-1} NPK × 5 irrigations (30, 55, 80, 105 and 130 DAS) proved to be optimum for achieving results from cotton variety Sindh-1. Similar results have also been reported by **[58-61]** who revealed that cotton crop is prone to insect pest infestation and environmental stress; and only judicious use of fertilizers and irrigation water would be effective and economically profitable for the cotton growers. They have also suggested scientific modeling for irrigation management considering precipitation and temperature forecast and soil analysis for moisture and available nutriments.

Conclusions and Recommendation

NPK fertilizers at the rates of 124-62-62 kg ha^{-1} showed most promising results avoiding excessive growth, resulted in increased and heavier opened bolls with higher single plant seed cotton and lint weight as well as seed and lint yield ha^{-1} as compared to RDF (112-56-56 kg ha^{-1} NPK). The effect of irrigation regimes showed that the crop receiving 7 or 6 irrigations showed statistical similarity ($P>0.05$) for plant height; while 5 irrigations resulted in higher overall agronomic performance. Under water stress, the variety Sindh-1 has proved to be highly economical to produce quality crop with lower irrigation frequency of five irrigations during entire cotton growth period. Hence, the interactive effect of NPK rate of 124-62-62 kg ha^{-1} and 5 irrigation resulted in highly economic output as compared to recommended NPK and greater irrigation levels. The cotton growers on adoption of cotton variety Sindh-1 could save a considerable amount of water which can be utilized to raise other crops or to bring addition area under cotton cultivation. It is recommended that the cotton growers should fertilizer cotton variety Sindh-1 with NPK at the rate of 124-62-62 kg ha^{-1} and five irrigations would be enough if gently managed by considering the critical growth period and climatic conditions. The farmers are suggested to adopt local promising cotton variety Sindh-1 which is higher yielder as well as needs less water under higher NPK fertilizers.

Authors' contributions

Conducted experiment and wrote first draft of manuscript: MA Zardari & AA Soomro, Supervised the experiment and helped in technical writing: AA Soomro, Technical guidance throughout my research: MH Khan & NS Memon, Corrected this manuscript: MH Khan, R Karim, A Nadeem & NS Memon, Formatted this manuscript and helped statistical analysis: MA Zardari, R Kaim & A Nadeem: Helped in data collection: AA Soomro.

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References

1. Rehman A, Jingdong L, Chandio AA, Hussain I, Wagan SA &. Memon QUA (2019). Economic perspectives of cotton crop in Pakistan: A time series analysis (1970–2015) (Part 1). *J Saudi Soc Agri Sci* 18: 49–54.
2. Shahbandeh M (2022). Top cotton exporting countries 2021/2022. https://www.statista.com/statistics/191895/leading-cotton-exporting-countries/
3. GOP (2019). Cotton: Pakistan Economic Survey 2019-20, Finance division, Economic Advisor's wing, Islamabad. pp. 19.
4. PCPA (2015). Pakistan Cotton and Products Annual. 2015. Global Agricultural Information Network (GAIN). 1 April 2015. Retrieved 13 November 2015.
5. PSC (2015). Pakistan's Punjab Seed Council Holds Approval of Bt and Non-Bt Cotton Varieties. Punjab Seed Council,

https://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=14390
6. Fatima H, Khan MA, Zaid-Ullah M & Saddozai KN (2016). Technical efficiency of cotton production in Pakistan: A comparative study on non Bt and Bt-cotton farms. *Sarhad J Agric* 32(4).
7. Maharana L, Dash PP & Krishnakumar, KN (2011). A comparative assessment of BT and non-BT cotton cultivation on farmers' livelihood in Andhra Pradesh.*J Biol Sci Res* 2(2): 99-111.
8. Sarwar M, Saleem MF, Wahid MA, Shakeel A & Bilal MF (2012). Comparison of Bt and non-Bt cotton (*Gossypium hirsutum* L.) cultivars for earliness indicators at different sowing dates and nitrogen levels. *J Agric Res* 50(3): 335-347.
9. Schofield A & Haigh S (2017). Disturbed Soil Properties and Geotechnical Design (Book), Second edition. ICE Virtual Library: https://www.icevirtuallibrary.com/isbn/9780727761552.
10. Aimen A, Basit A, Aslam BZ, Shahid, MF & *et al.* (2022). Sustainable phosphorous management in two different soil series of Pakistan by evaluating dynamics of phosphatic fertilizer source. *Saudi J of Biol Sci* 29(1): 255-260.
11. Yang L, Bai J, Liu N, Zeng & Cao W (2018). Green Manuring Effect on Changes of Soil Nitrogen Fractions, Maize Growth, and Nutrient Uptake. *Agron* 8: 261-273.
12. Jagannathan. NT & Venkitaswamy R (1996). Effect of plant density and nutrient levels on new cotton varieties. *Madras Agric J* 83: 159-161.
13. Abdel-Malak, KKI (2005). The proper irrigation intervals for vegetative and fruiting stages of cotton cultivar Giza 83. *Egy J of Agric Res* 76(2): 765-772.
14. Kumbhar AM & Kumbhar SA (2008). Impact of different nitrogen levels on cotton growth, yield and N-uptake planted in legume rotation. *Pak J Bot* 40(2): 767-778.
15. Augostinho LMD, Prado RM, Rozane DE & Freitas N (2008). Acúmulo de massa seca e marcha de absorção de nutrientes em mudas de goiabeira 'Pedro Sato'. *Bragantia*, 67: 577-585.
16. Carvalho MCS (2007). Adubação de cobertura do algodoeiro cultivado em condições de sequeiro na região do Cerrado. Campina Grande: Embrapa Algodão; 2007. *(Comunicado Técnico*, 347).
17. Bruulsema TW, Fixen PE & Sulewski GD (2012). 4R plant nutrition: a manual for improving the management of plant nutrition. Norcross: *Inter Plant Nutr Institute*.
18. Rochester IJ & Constable GA (2015). Improvements in nutrient uptake and nutrient use-efficiency in cotton cultivars released between 1973 and 2006. *Field Crop Res* 173:14-21.
19. Gowda A, Rydel TJ, Wollacott AM, Brown RS, Akbar W & Baum JA (2016). A transgenic approach for controlling *Lygus* in cotton. *Nat Commun* 7:12213.
20. Constable GA & Bange MP (2015). The yield potential of cotton (*Gossypium hirsutum* L.). *Field Crops Res* 182: 98-106.
21. Trapero C, Wilson IW, Stiller, WN & Wilson LJ (2016). Enhancing integrated pest management in GM cotton systems using host plant resistance. *Front Plant Sci* 7: 500.
22. Rosolem CA, Echer, FR Lisboa IP & Barbosa TS (2012). Acúmulo de nitrogênio, fósforo e potássio pelo algodoeiro sob irrigação cultivado em sistemas convencional e adensado. *Rev Bras Cienc Solo* 36: 457-66.
23. Yang L, Bai J, Liu N, Zeng & Cao W (2018). Green Manuring Effect on Changes of Soil Nitrogen Fractions, Maize Growth, and Nutrient Uptake. *Agron* 8: 261-273.
24. Mubarak I & Janat M (2018). Response of new cotton variety (Rassafa) to nitrogen fertilizer. *The Open Agric J* 12: 104-112.
25. Howell TA, Evett SR, Tolk JA & Schneider AD (2004). Evapotranspiration of full deficit irrigated, and dryland cotton on the

northern Texas high plains. *J Irrig Drain Eng* 130: 277–285.
26. Xi-ping D, Shan L, Zhang H & Turner NC (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.
27. Economic Survey of Pakistan (2017-18). Cotton: Finance division, Economic Advisor's wing, Government of Pakistan, Islamabad, pp. 19.
28. Goyne PJ & McIntyre GT (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.
29. Bhattarai SP (2005). The physiology of water use efficiency of crops subjected to subsurface drip irrigation, oxygation and salinity in a heavy clay soil. PhD. Thesis, School of Biol Env Sci, Faculty of Arts, Health & Sci, Central Queensland Univ. Rockhampton, QLD 4702, Australia.
30. Khan MM, Khilji AR & Taran SA (2011). Effects of Row Spacing on the Growth and Yield of Sunflower Varieties. LAP Lambert Academic Publishing Co. pp. 88.
31. Aujla MS & Butter GS (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.
32. Jalota SK, Sood A & Choudhury BU (2006). Crop water productivity of cotton (*Gossypium hirsutum*L.) wheat (*Triticum aestivum*L.) system as influenced by deficit irrigation, soil texture and precipitation. *Agric Water Manag* 84(1-2): 137-146.
33. Harris, G. (2006). Irrigation water balance scheduling. AFFS Farming Systems, DPI and Staff of Australian Cotton Cooperative Research Centre. pp. 1-5.
34. Shahbandeh M (2022). Top cotton exporting countries 2021/2022. https://www.statista.com/statistics/191895/leading-cotton-exporting-countries/
35. GOP (2019). Cotton: Pakistan Economic Survey 2019-20, Finance division, Economic Advisor's wing, Islamabad. pp. 19.
36. PCPA (2015). Pakistan Cotton and Products Annual. 2015. Global Agricultural Information Network (GAIN). 1 April 2015.
37. English MJ, Solomon KH & Homan, GA (2002). A paradigm shift in irrigation management. *J Irrig Drain Eng* 128: 267–277.
38. Statistix (2006). *S*tatistical analysis program version 8.1 (sxw.exe). Analytical Software 2105 Miller Landing Rd, Tallahassee, FL 32312
39. Rehman A, Jingdong L, Chandio AA & Memon QUA (2019). Economic perspectives of cotton crop in Pakistan: A time series analysis (1970–2015) (Part 1). *J Saudi Soc Agri Sci* 18: 49–54.
40. Harris G (2006). Irrigation water balance scheduling. AFFS Farming Systems, DPI and Staff of Australian Cotton Cooperative Research Centre. pp. 1-5.
41. Ahmad HS, Imran M, Ahmad F & *et al.* (2021). Improving Water Use Efficiency through Reduced Irrigation for Sustainable Cotton Production. *Sustain* 13 (4044): 1-12.
42. Bicksler AJ & Masiunas JB (2009). Canada thistle (Cirsium arvense) suppression with Buck wheat or Sudangrass cover crops and mowing. *Weed Technol* 23 (4): 556-563.
43. Guo JH, Liu XJ, Zhang Y, Shen J, Han W, Zhang W, Christie P, Goulding K, Vitousek P & Zhang F (2010). Significant acidification in major Chinese croplands. *Sci* 327: 1008-1010
44. Koulibaly B, Dakuo D, Ouattara A, Traoré O & *et al.* (2015). Effets de l'association du compost et de la fumure minérale sur la productivité d'un système de culture à base de cotonnier et de maïs au Burkina Faso. *Tropicultura* 33(2):125-134.
45. Saleem, M, Maqsood, M Hussain, A (2008). Impact of integrated plant nutrition and irrigation scheduling on the yield and

quality of cotton. *Pak J Agric Sci* 45(1): 34-39.
46. Wajid N, Hatem B, Muhammad TM & Rafiq A (2015). Correlation studies on nitrogen for sunflower crop across the agroclimatic variability. *Environ Sci Pollut Res*.
47. Marco DE, Perez-Arnedo R, Hidalgo-Perea A, Olivares J, Ruiz-Sainz JE & Sanjuan J (2009). A mechanistic molecular test of the plant-sanction hypothesis in legume-rhizobia mutualism. *Acta Oecol-Inter J of Ecol* 35: 664-667.
48. Dakuo D, Koulibaly B, Ouattara K, Lompo F & Yao-Kouamé A (2016). Potassium Fertilization Efficiency on Cotton (*Gossypium hirsutum*L.) Nutrition and Crops Yields on Three Soil Types in Burkina Faso. *Academia J of Agric Res* 4(11): 647-651.
49. Gupta A & Sahu PK (2017). Phosphorus Nutrition of Plants: A Microbial Perspective. *MOJ Eco Environ Sci* 2(6).
50. Bruulsema TW, Fixen PE & Sulewski GD (2012). 4R plant nutrition: a manual for improving the management of plant nutrition. Norcross: *Inter Plant Nutr Institute* 2012.
51. Rochester IJ & Constable GA (2015). Improvements in nutrient uptake and nutrient use-efficiency in cotton cultivars released between 1973 and 2006. *Field Crop Res* 173: 14-21.
52. Guo JH, Liu XJ, Zhang & Zhang F (2010). Significant acidification in major Chinese croplands. *Sci* 327: 1008-1010.
53. Abbas S, Dastgeer G, Yaseen M & Latif Y (2022). Land-use change impacts on soil and vegetation attributes in the Kanshi River basin, Potohar Plateau, Pakistan. *Land Degrad & Devel* 33(15): 2649-2662.
54. Ali A, Rahut,DB & Mottaleb KA (2018). Improved water-management practices and their impact on food security and poverty: empirical evidence from rural Pakistan. *Water Pol* 20(4): 692-711.
55. Araújo WP, Pereira JR., Zonta JH, Guerra HOC, Cordao MA, & de Lima RF (2019). Production components and water efficiency of upland cotton cultivars under water deficit strategies. *Afri J of Agric Res* 14(20): 887-896.
56. Ali, MA. Farooq, J, Batool, A, Zahoor, A, Azeem F, Mahmood A & Jabran K (2019). Cotton production in Pakistan. *Cotton Prod* 249-276.
57. PSC (2015). Pakistan's Punjab Seed Council Holds Approval of *Bt* and Non-*Bt* Cotton Varieties. Punjab Seed Council, https://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=14390
58. Fatima H, Khan MA, Zaid-Ullah M & Saddozai KN (2016). Technical efficiency of cotton production in Pakistan: A comparative study on non Bt and Bt-cotton farms. *Sarhad J Agric* 32(4).
59. Jalota SK, Sood A, Chahal GBS & Choudhury BU (2006). Crop water productivity of cotton (*Gossypium hirsutum*L.) wheat (*Triticum aestivum*L.) system as influenced by deficit irrigation, soil texture and precipitation. *Agric Water Manag* 84(1-2): 137-146.
60. Harris G (2006). Irrigation water balance scheduling. AFFS Farming Systems, DPI and Staff of Australian Cotton Cooperative Research Centre. pp. 1-5.
61. Garcia AG, Persson T, Guerra LC & Hoogenboom G (2010). Response of soybean genotypes to different irrigation regimes in a humid region of the southeastern USA. *Agric Water Manag* 97(7): 981-987.