OPTIMAL NUTRIENT REQUIREMENT OF NEWLY DEVELOPED COTTON VARIETY SINDH-1

M.A. Zardari[*], A.A. Soomro[*], M.N. Kandhro[*], N. Laghari[**] and N.S. Memon[***]

[*]Agronomy Dept, Sindh Agri.. University Tandojam
[**]Farm Power & Machinery Dept, Sindh Agri.. Univ. Tandojam
[***]Department of Soil Science, Sindh Agri.. Univ. Tandojam

ABSTRACT

Cotton, the 'silver gold ' is solitary source of raw material for Pakistan textile industry. Rapid replacement of locally cultivated cotton varieties with Bt-cotton demands the revision of production technologies including fertilizer recommendations; because mostly the seed of Bt cotton varieties being adopted is imported without assessment of the soil and climatic suitability for these varieties locally. A newly evoleved most promising cotton variety Sindh-1 was evaluated against various fertilizer levels (136-68-68 kg: 20% >RDF [recommended dose of fertilizers]; 124-62-62 kg: 10% >RDF; 112-56-56 kg: RDF; 100-50-50 kg: 10% <RDF; 88-44-44 kg ha^{-1}: 20% <RDF) to optimize its NPK requirement. The results showed that 124-62-62 kg ha^{-1} NPK (10% >RDF) produced most promising agronomic performance than RDF (112-56-56 kg). It indicates that the soils have become more deficient of essentially required elements and existing RDF (NPK 112-56-56 kg ha^{-1}) is no more economically viable rate and needs to be revised upto 124-62-62 kg ha^{-1}. The farmers may be advised for adoption of promising local cotton variety Sindh-1 which is not only high yielding, but also more responsive to NPK fertilizers as compared to other cotton varieties under cultivation.

KEYWORDS: Cotton, variety Sindh-1, NPK, growth, lint yield and quality and oil content

INTRODUCTION

Cotton (*Gossypium hirsutum* L.), recognisingly known as "white gold" is a profitable fiber crop of Pakistan; and considered as potential source of sustainable development of national economy. Apart from its significance as raw material for global textile industry, cotton is also a major source of edible oil production (Rehman *et al*., 2019). Worldwide, Pakistan ranks 4th in cotton production (1785 thousand tons) after India, China, United States and Brazil producing 6205, 5987, 4555 and 1894 thousand tons, respectively; but US is the main exporter of raw cotton ($6.147 billion), followed by Brazil, Australia and India (Statistica, 2018). However, Pakistan exported cotton valuing US$2.64 billion during 2020; while China and USA remained the main partners in export-import of cotton (Daniel Workman, 2021). In Pakistan, cotton crop was sown on an area of 2,079 thousand ha during 2020-21 showing 17.4% decrease over last year's area (2,517 thousand ha). During 2020-21, the national production remained 7.064 million bales showing 22.8% decrease over the last year's production of 9.149 million bales.

Presently, the seed cotton yield is 578 kg, indicating 6.5% decrease over last year's yield (618 kg ha^{-1}). 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 cotton yield ha. The flaws in government policies on cotton price and lack of incentives to growers remained the main causes; while lack of information about optimum nutrients and use of unapproved cotton varieties have also added to this deteriorated situation. Probably, imported seed was used excessively without any propr testing in local environment, and cotton growers are entirely dependent on seed marketing companies having nothing to do with soil and climatic suitability of the growers (Shuli *et al*. 2018). Potentially, the annual cotton production could normally be achieved upto 20 million bales; if the cotton is managed properly for nutrients (Economic Survey of Pakistan, 2021).

Cotton crop in Pakistan is challenged by a variety of issues which mainly include balanced use of nutrients. Swift replacement of local commercial cotton varieties with Bt cotton has left the cotton growers chaotic about nutrient requirement of new varieties the as non-Bt cotton has promptly been substituted with the Bt cotton (PCPA, 2015; Fatima *et al.*, 2016). Due to continuous cropping without soil amendment for improving organic matter, soils are deteriorated and do not produce potential cotton yields (Yang *et al.*, 2018). The yields were potentially achieved with different NPK doses, depend on the soil quality. In order to achieve maximum seed cotton yields in Indian soils, 150-75-75 kg ha^{-1} NPK was used (Jagannathan and Venkitaswamy, 1996); in Egyptian soils 90-15-30 kg NPK ha^{-1} (Abdel-Malak, 2005); and in Pakistan N application is ranged in between 90-140 kg ha^{-1} alongwith 60 kg P and 50 kg K ha^{-1}; while in Sindh province of Pakistan recommended dose of NPK for cotton is 112-56-56 kg ha^{-1} (Soomro *et al.*, 2001; Shuli *et al*., 2018). The variation in NPK requirement is associated with the soil health, soil management and cropping intensity. In earlier studies (Kumbhar *et al.*, 2008), 150-50 NP kg ha^{-1} has been suggested for cotton. However, optimistic rate of nutriuents needs to have specific knowledge of cotton varieties for their nutrient requirements considering their nutrient uptake on the basis of soil and plant analysis (Augostinho *et al*., 2008; Carvalho, 2007). The nutrient requirement and uptakes of a cotton variety can only be determined by its need at its various phenological stages to develop adoptable nutritional management approach (Bruulsema *et al*., 2012). It is generally concluded that new cotton varieties are developed with improved NPK use efficiency (Rochester and Constable, 2015; Gowda *et al*., 2016); and these may vary in response to applied inputs (Constable and Bange, 2015**;** Trapero *et al*., 2016); while varieties evaluated for their nutrient requirement in the past have already been replaced by newly evolved varieties (Rosolem *et al*., 2012). Therefore, the production technologies including existing nutrient recommendations need to be optimized for their NPK requirement under different ecological zones (Yang *et al.*, 2018; Mubarak and Janat, 2018). The objective behind this research was to enhance seed cotton yield and quality by application of improved nutrition management. Thus, the study was aimed at finding the optimum nutrient requirement of the most promising cotton variety Sindh-1 under soil and climatic conditions of Tandojam, District Hyderabad, Sindh (Pakistan).

METHODOLOGY

Agriculture Research Center (experimental site) Tandojam, district Hyderabad (Sindh province) is located at 25°26'^{O}N latitude and 68°32'^{O}E longitude. Promising cotton variety (Sindh-1) was tested to optimize its NPK requirement during Kharif seasons (2017 and 2018). The soil at start was worked well by dry plowing and then supplied with soaking dose. Precision land leveler was operated to get the soil surface leveled so that the experimental crop may get irrigation water evenly, followed by cultivator plowing and planking. 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 inter and intra row spacing. The seed was sown by drilling method in in three replicated RCB Design. The NPK fertilizers were applied as per the treatment plan. All P and K in addition to half N were applied as basal application as urea, DAP and SOP, respectively; while remaining half of N was split in two doses. The xperimental crop was irrigated as per the recommended frequency. The recommended plant protection measures for control of weeds, insect pests and diseases were adopted. In order to combat sucking complex, Lambda 200SL and Radiant/120SC were sprayed; while bollworm complex was controlled by Coragen 120SC spray. The 1st picking was done at the time of 50% boll opening, while later picking were done at 20 days interval.

Procedures adopted for measuring soil properties and crop traits

Texture and physicochemical properties of soil

Bouyoucos Hydrometer method (Bouyoucos, 1962) was used analyse soil texture; while digital conductivity meter for determing soil EC, followed method No.3c.P. 88, mentioned in "Diagnosis and Improvement of Saline and Alkali Soils" (Agri. Hand Book No.60. USDA, 1954). The digital pH meter (model SP-34 Suntex) was used to determine soil pH (as suggested in Prac. Agri. Chem., Kanwar and Chopra, 1959); Walkely-Black method as described in soil chemical analysis (Jackson, 1958; No.9.65-68.p, 220) was applied to measure the soil OM. Kjedahl method (Soil chemical analysis, 1958; Method No. 84, Pp183) was applied to determine total N; while available P and extractable K were determined By AB-DTPA method (Soltanpour and Sehwab, 1985) using spectrophotometer.

Agronomic indices

The plant height was measured by 0.01cm measuring tape; and monopoial and sympodial branches, total bolls, opened/unopened bolls plant^{-1} were visually counted in randomly selected five plants in each plot. Seed-cotton, seed and lint weights boll^{-1} were recorded on the basis of 20 bolls from each plot using electronic top loading balance and then averaged for single boll. The seed-cotton, seed and lint weights plant^{-1} were recorded on the basos of randomly selected five plants in each plot and averaged. After separating the seeds from seed cotton by ginning, 1000 seeds were taken at random from each treatment of three replicates and weighed as seed index. To obtain total seed cotton yield, the seed cotton obtained from each treatment of three replicates was weighed and mean was calculated for one plot; per hectare yield was calculated on the basis of per plot yields. The staple length (mm) was determined by combining the fiber and was measured by a graduated plastic disc; while to record GOT, seed cotton was ginned by electronic ginner in Cotton Research Institute, ARC Tandojam. The lint and seed was weighed separately and the weight of lint was divided by the seed cotton weight and multiplied by hundred; this percentage was expressed as ginning out turn (GOT %). For oil content, the oil was extracted through soxhelete apparatus and extracted oil was measured, this quantity of oil was divided with the weight of seed used to extract oil and multiplied by hundred; this figure was considered as the percent oil content.

Soil analysis

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

TABLE – I 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

Note: 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)

Table 2 explains the physico-chemical properties of the experimental soil determined using composite samples of the experimental site. It was noted that before sowing, the soil had average pH value of 7.08, EC 0.36 dS/m^{-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 picking of cotton and used for similar analysis. After cotton picking, soil pH averaged 7.90, EC 0.66 dS/m^{-1}, OM 1.92%, $CaCO_3$ 6.30%, total N 0.058%, available P 0.86% and extractable K 26.80%. After picking, the physico-chemical properties of the significantly increased. The pH was somewhat increased but was not adverse, $CaCO_3$, total N, available P and extractable K were improved considerably. The results suggested increased application of NPK fertilizers amended the soil at experimental site positively.

TABLE – II 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

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.

RESULTS AND DISCUSSION

Optimize nutrient requirement for cotton variety Sindh-1

In order to optimize nutrients, the five NPK levels were evaluated against cotton variety Sindh-1. The data (Table 3) showed that all the growth, seed and lint yield traits were significantly (P<0.05) influenced by NPK rates. The cotton plants grew tallest (95 cm) with maximum sympodia (9.53) and monopodia (1.40 plant^{-1}), unopened bolls (4.53 plant^{-1}) and staple length (27.76 mm) when NPK fertilizers were applied 20%>RDF (136-68-68 kg ha^{-1}). The sympodia and monopodia as well as unopened bolls plant^{-1} showed trend similar to plant height; and with excessive growth, the branching was slightly increased (P>0.05) but opening of bolls were checked a little and increase in unopened bolls occurred. The NPK fertilizers when applied 10%>RDF (124-62-62 kg ha^{-1}), performed best for seed and lint yields as well as other traits including opened bolls (18.20 plant^{-1}), seed cotton weight boll^{-1} (3.08 g), seed cotton weight plant^{-1} (131.70 g), seed weight plant^{-1} (85.60 g), lint weight plant^{-1} (46.10 g), seed cotton yield (3226.9 kg ha^{-1}), seed yield (1971.7 kg ha^{-1}), lint yield (1255.2 kg ha^{-1}), GOT (38.91%), staple length (27.54 mm) and oil content (25.62%).

The existing RDF (112-56-56 kg ha^{-1}) could not demonstrate better results compared to the cotton crop receiving 10 or 20>RDF. The cotton crop fertilized with NPK at the rate of 100-50-50 kg ha^{-1} (10%<RDF) or 88-44-44 kg ha^{-1} (20<RDF) only maximized unopened bolls number (4.54 and 4.87 plant^{-1}), respectively; while the values for all the remaining traits of economic importance of cotton declined. It is apparent that for achieving desirable cotton yields, the crop needs NPK fertilizers at increased rates (124-62-62 kg ha^{-1}) over existing RDF (112-56-56 kg ha^{-1}). The crop fertilized with NPK at the levels of 124-62-62 kg ha^{-1} showed most promising results avoiding excessive plant growth, producing increased and heavier opened bolls with higher single plant seed cotton and lint weight as well as seed and lint yield ha^{-1}. The values of GOT, staple length as well as oil content were also higher in cotton fertilized with 124-62-62 kg ha^{-1} NPK level as compared to existing RDF. It is suggested that NPK fertilizers at the rate of 124-62-62 kg ha^{-1} may be recommended for achieving desirable yields and quality lint in cotton.

This study identified that existing RDF (112-56-56 kg ha^{-1}) has lost its validity as an optimum level for cotton; and needs to be revised and replaced by 10% increase (124-62-62 kg ha^{-1} NPK) on the basis of findings related to growth, seed/lint yields, oil content and lint quality traits. Rehman *et al.* (2019) have suggested that cotton varieties are cultivated across the country without registration in the local ecological conditions. They argued that variety specific nutrients and irrigation levels may be developed. Ashraf *et al.* (2018) have also reported that with the deteriorating soil fertility status and increasing salinity, the recommendations regarding fertilizers need to be optimized frequently. Ahmad *et al.* (2021) have suggested that locally developed cotton varieties must be examined for their input requirements due to fast changing soil and climatic status in Pakistan. The role of NPK in achieving desired crop yields is inevitable (Bicksler and Masiunas, 2009). Decline in soil fertility is susceptible to sustainability (Guo *et al.*, 2010) and such soil conditions in countries operating with conventional agriculture is devastating (Koulibaly *et al*., 2015). There is immediate need to assess the existing fertilizer recommendations and optimize them under recent climate change condition to ensure sustainable food production (Saleem *et al.,* 2008*)*. Wajid *et al*. (2015) stressed that fertilizer recommendations should be continuously kept under observation to optimize them due to climate change and subsequent soil nutrient deterioration. Gupta and Sahu (2017) also favored the findings of the present research and urged continuity of ecological studies so that the changing soil and climatic may be taken into consideration while experimental conclusions are developed.

The deteriorating status of soil available nutrients and acute shortage of irrigation water have become major challenges to achieve potential yields. The past reports revealed that soils were only deficient of N, but the recent researches have detected soil P and K deficiency as well (Dakuo *et al*., 2016). Marco *et al.* (2009) suggested that NPK requirements of cotton is mainly associated with the soil type, soil quality and cropping patterns. If the soil is kept under continuous cropping without organic amendments, its nutrient status could deteriorate. However, under these circumstances, the soil NPK requirements may change fast. Yang *et al.* (2016) and Sui *et al.* (2017) argued inter and intra region soil variations and sometimes inter region soil variation is markedly higher than the intra regional variations. Latif *et al.* (2016) concluded that with change in the soil temperature and deteriorating soil nutrient levels, the recommendations for soil applied nutrients needs revision. Shareef *et al.* (2018) 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 nutriuent requirements are timely optimized.

The recommendation of NPK and irrigation regime combination 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. Sial *et al.* (2014), Latif *et al.* (2016), Sattar *et al.* (2017) and Ahmad *et al.* (2021) 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 suggested scientific modeling for irrigation management considering precipitation and temperature forecast and soil analysis for moisture and available nutriuents.

FIGURE – I PLANT HEIGHT (cm)

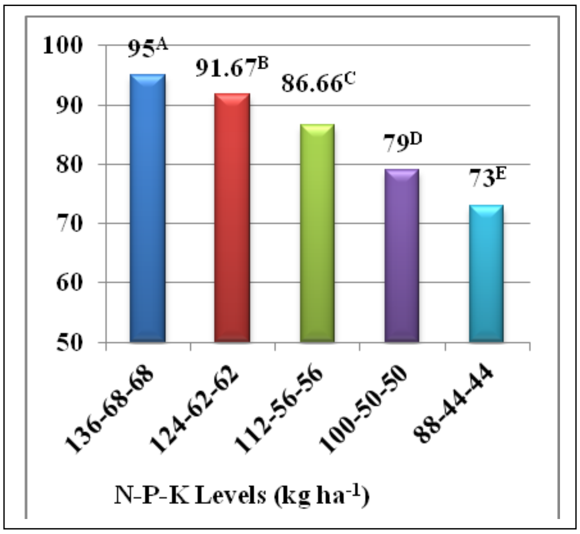
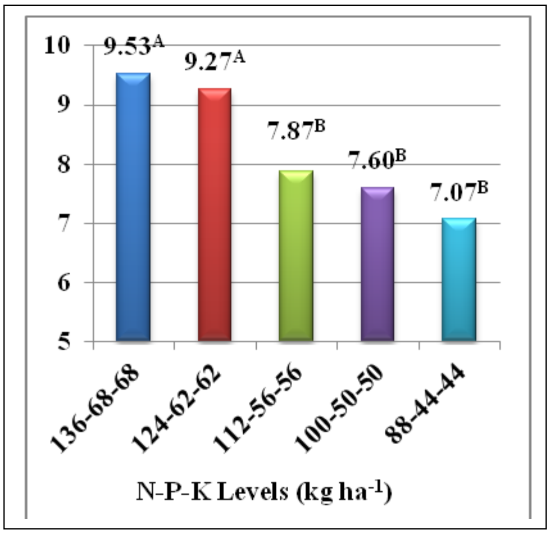
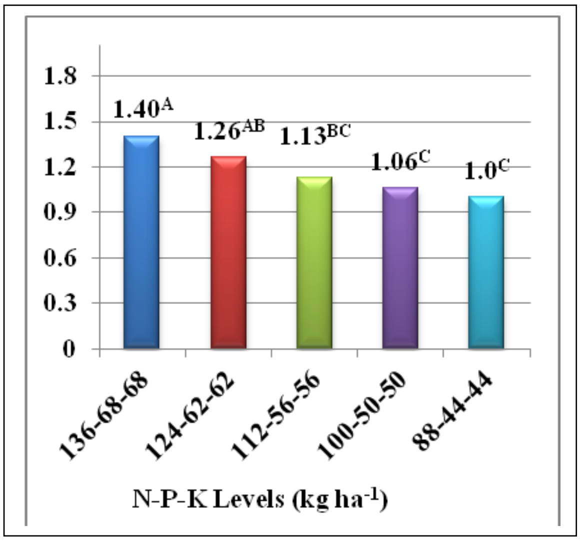


FIGURE – II NO.OF SYMPODIAL BRANCHES PLANT^{-1}





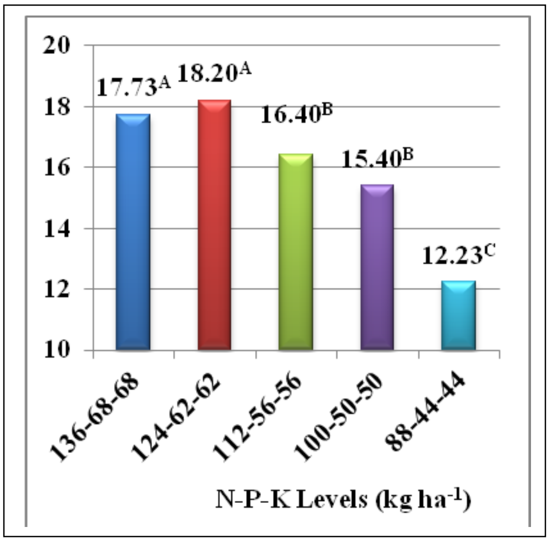


Fig-3: No.of monopodial branches plant^{-1} **Fig-4: No.of opened bolls plant^{-1}**

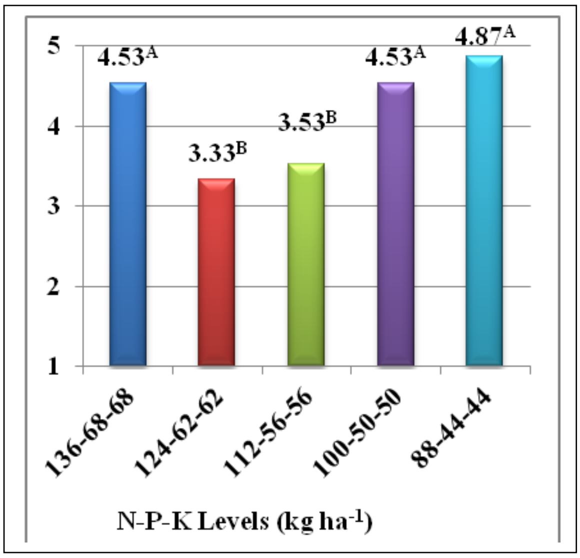


Fig-5: No.of unopened bolls plant^{-1}

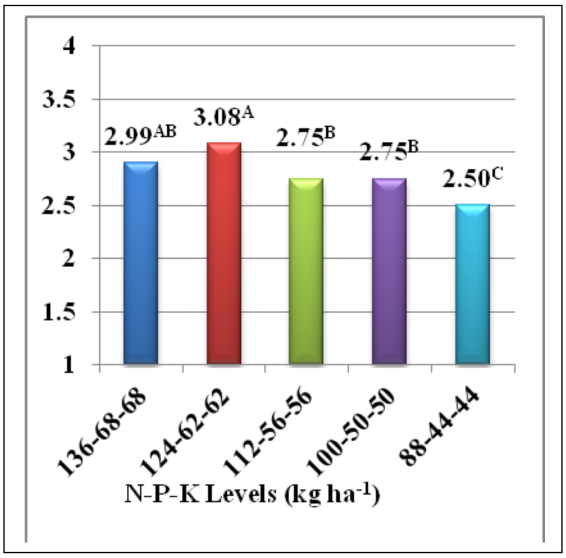


Fig-6: Seed cotton weight boll^{-1}(g)

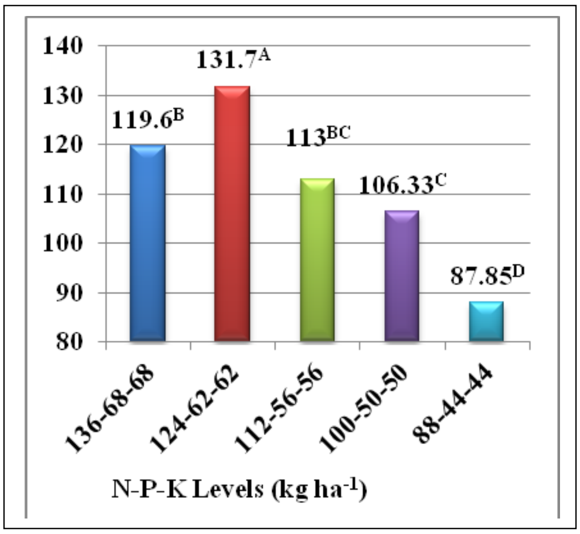


Fig-7: Seed cotton weight plant^{-1} (g)

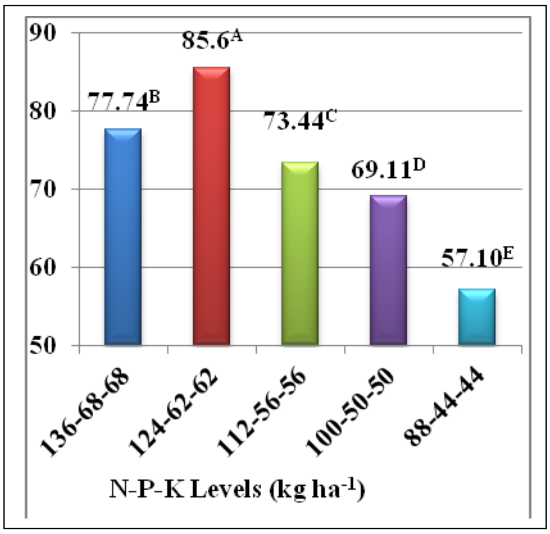
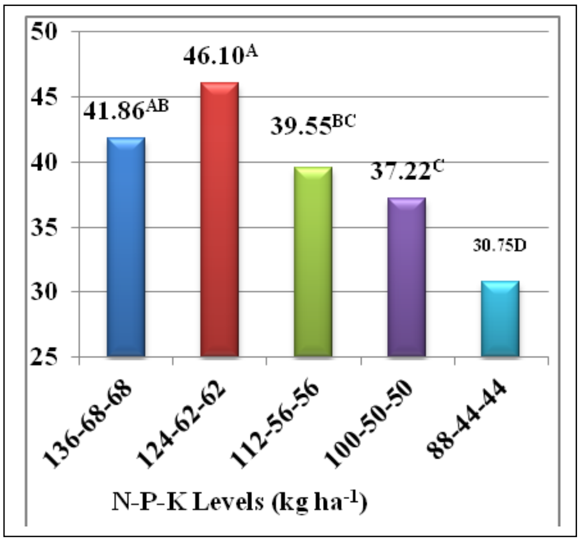


Fig-8: Seed weight plant^{-1} (g)



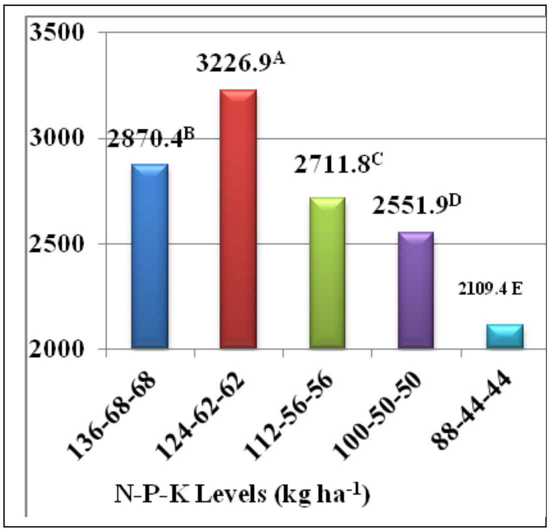
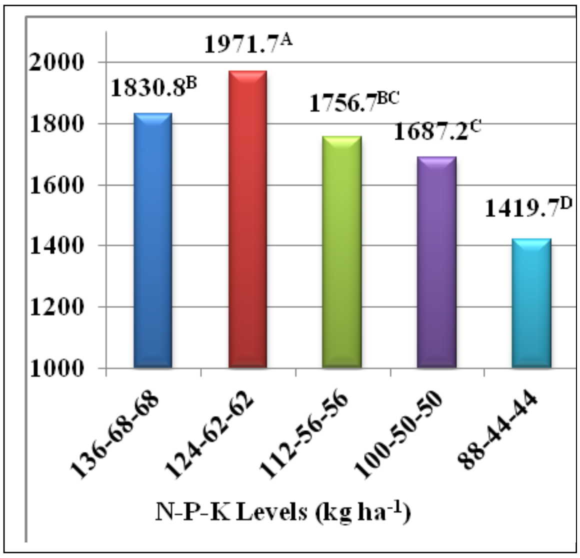


Fig-9: Lint weight plant^{-1} (g)

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



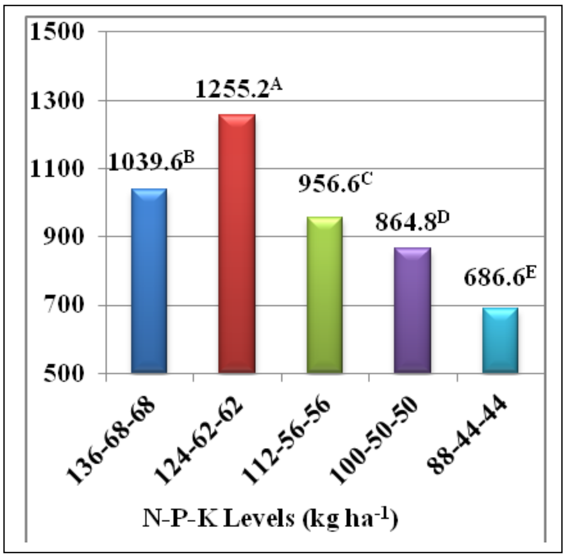
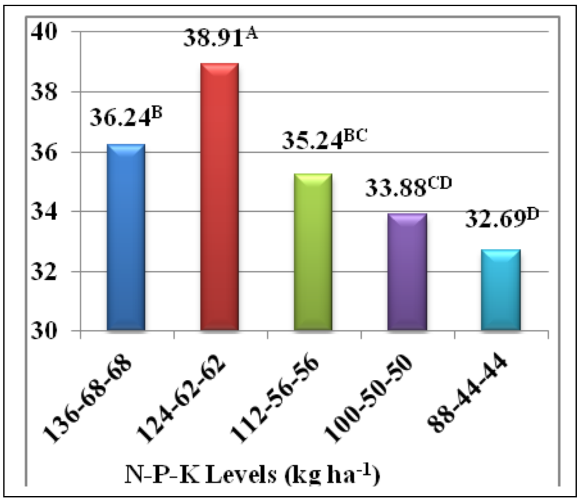


Fig-11: Seed yield ha^{-1} (kg)

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



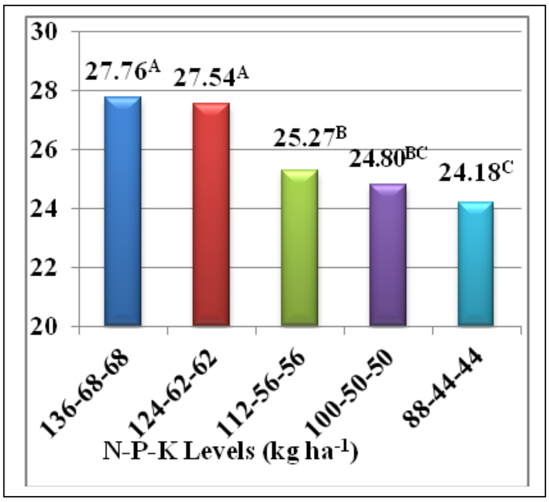


Fig-13: Ginning out-turn (%)

Fig-14: Staple length (mm)

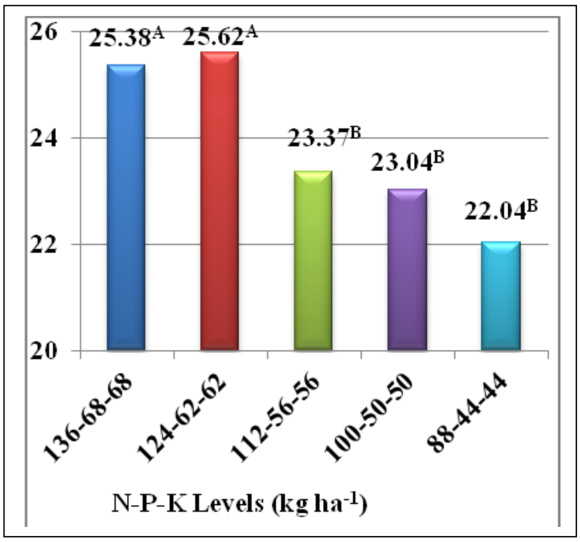


Fig-15: Oil content (%)

CONCLUSION

NPK at the rates of 124-62-62 kg ha^{-1} (10% >RDF) showed most promising results avoiding excessive growth, resulted in increased and heavier opened bolls with higher single plant seed cotton as well as seed and lint yield ha^{-1} as compared to RDF (112-56-56 kg ha^{-1} NPK). Hence, NPK fertilizers at the rate of 124-62-62 kg ha^{-1} resulted in highly economical output as compared to existing recommended NPK for cotton.

RECOMMENDATION

It is suggested that the existing NPK recommendation (112-56-56 kg ha^{-1}) needs to be raised upto 124-62-62 kg ha^{-1} for the promising cotton variety Sindh-1. The farmers may be advised for adoption of promising local cotton variety Sindh-1 which is not only higher yielding, but also more responsive to NPK fertilizers as compared to other cotton varieties under cultivation.

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.

Augostinho, L.M.D., R.M. Prado, D.E. Rozane and N. Freitas. 2008. Acúmulo de massa seca e marcha de absorção de nutrientes em mudas de goiabeira 'Pedro Sato'. Bragantia, 67:577-85.

Bicksler, A.J. and J.B. Masiunas. 2009. Canada thistle (Cirsium arvense) suppression with Buck wheat or Sudangrass cover crops and mowing. Weed Technology, 23 (4):556-563.

Bruulsema, T.W., P.E. Fixen and G.D. Sulewski. 2012. 4R plant nutrition: a manual for improving the management of plant nutrition. Norcross: International Plant Nutrition Institute; 2012.

Carvalho, M.C.S. 2007. Adubação de cobertura do algodoeiro cultivado em condições de sequeiro na região do Cerrado. Campina Grande: Embrapa Algodão; 2007. (Comunicado Técnico, 347).

Constable, G.A. and M.P. Bange. 2015. The yield potential of cotton (*Gossypium hirsutum* L.). Field Crops Res., 182:98-106.

Dakuo, D., B. Koulibaly, K. Ouattara, F. Lompo and A.Yao-Kouamé. 2016. Potassium Fertilization Efficiency on Cotton (*Gossypium hirsutum*L.) Nutrition and Crops Yields on Three Soil Types in Burkina Faso. Academia Journal of Agricultural Research, 4(11): 647-651.

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

Gowda, A., T.J. Rydel, A.M. Wollacott, R.S. Brown, W. Akbar, T.L. Clark, S. Flasinski, J.R. Nageotte, A.C. Read, X. Shi, B.J. Werner, M.J. Pleau and J.A. Baum. 2016. A transgenic approach for controlling *Lygus* in cotton. Nat Commun., 7:12213.

Gupta A. and P.K. Sahu. 2017. Phosphorus Nutrition of Plants: A Microbial Perspective. MOJ Eco. Environ. Sci. 2(6): 00043. DOI: 10.15406/mojes.2017.02.00043.

Jagannathan. N.T. and R. Venkitaswamy, 1996. Effect of plant density and nutrient levels on new cotton varieties. Madras Agric. J., 83: 159-161.

Koulibaly, B., D. Dakuo, A. Ouattara, O. Traoré, F. Lompo, P.N. Zombré, A. Yao-Kouamé. 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.

Kumbhar, A.M., U.A. Buriro, S. Junejo, F.C. Oad, G.H. Jamro, B.A. Kumbhar and S.A. Kumbhar. 2008. Impact of different nitrogen levels on cotton growth, yield and N-uptake planted in legume rotation. Pak. J. Bot., 40(2): 767-778.

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.

Marco, D.E., R. Perez-Arnedo, A. Hidalgo-Perea, J. Olivares, J. E. Ruiz-Sainz, and J. Sanjuan. 2009. A mechanistic molecular test of the plant-sanction hypothesis in legume-rhizobia mutualism. Acta Oecologica-International Journal of Ecology, 35:664-667.

Mubarak, I. and M. Janat. 2018. Response of new cotton variety (Rassafa) to nitrogen fertilizer. The Open Agriculture Journal, 12 : 104-112.

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.

Rochester, I.J. and G.A. Constable. 2015. Improvements in nutrient uptake and nutrient use-efficiency in cotton cultivars released between 1973 and 2006. Field Crop Res.,173:14-21.

Rosolem, C.A., F.R. Echer, I.P. Lisboa and T.S. Barbosa. 2012. Acúmulo de nitrogênio, fósforo e potássio pelo algodoeiro sob irrigação cultivado em sistemas convencional e adensado. Rev Bras Cienc Solo., 36:457-66.

Saleem, M., M. Maqsood and A. Hussain.2008. Impact of integrated plant nutrition and irrigation scheduling on the yield and quality of cotton. Pak. J. Agri. Sci., 45(1): 34-39.

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.

Shareef, M., D. Gui, F. Zeng, M. Waqas, B. Zhang and H. Iqbal. 2018. Water productivity, growth, and physiological assessment of deficit irrigated cotton on hyperarid desert-oases in northwest China. Agric. Water Manag, 206: 1–10.

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.

Sui, R., Byler, R.K., Delhom, C.D. 2017. Effect of nitrogen application rate on yield and quality in irrigated and rainfed cotton. Journal of Cotton Science, 21:113-121.

Trapero, C., I.W. Wilson, W.N. Stiller and L.J. Wilson. 2016. Enhancing integrated pest management in GM cotton systems using host plant resistance. Front Plant Sci., 7:500.

Wajid, N., B. Hatem, T. Muhammad, S. Fahad, M.H. Hafiz, M. Muhammad, F.H.M. Muhammad, J.C. Hassan, K. Imran, M. Faisal, A. Tauqeer, R. Fahd, N. Muhammad, A.B. Ali, U. Najeeb, F. Alghabari, S. Saud, M. Hussani and A. Rafiq. 2015. Correlation studies on nitrogen for sunflower crop across the agroclimatic variability. Environ. Sci. Pollut. Res. doi:10.1007/s11356-015-5613-1

Yang, J.S., H. Wei, W. Zhao, M.Y.C. Yali, W.Y. Youhua and Z. Zhou. 2016. Soil potassium deficiency reduces cotton fiber strength by accelerating and shortening fiber development. Sci. Rep. 6:28856.

Yang, L., Bai, J. Liu, N. Zeng and W. Cao. 2018. Green Manuring Effect on Changes of Soil Nitrogen Fractions, Maize Growth, and Nutrient Uptake. Agronomy, 8 : 261-273.

Soomro, A.H., S.A. Arain, A.R. Soomro, G. Tunio, M. Chang, A. Leghari and M. Mags. 2001. Evaluation of Proper Fertilizer Application for Higher Cotton Production in Sindh. Journal of Biological Sciences. 10.3923/jbs.2001.295.297.