Peruvian Journal of Agronomy
http://revistas.lamolina.edu.pe/index.php/jpagronomy/index

RESEARCH ARTICLE
https://doi.org/10.21704/pja.v8i2.1992

Received for publication: 2 March 2024
Accepted for publication: 2 May 2024
Published: 20 August 2024
ISSN: 2616-4477

NPK fertilization in the productive capacity and fiber quality of Tangüis Cotton (*Gossypium barbadense* L.)

Fertilización NPK en la capacidad productiva y calidad de fibra de algodón Tangüis (*Gossypium barbadense* L.)

Lorenzo Hurtado Leo[1], Giovanna Cajacuri Moreno[2]

[1] Universidad Nacional Agraria La Molina, Deparment of soils, Faculty of Agronomy, Irrigation Research Unit, Av. La Molina s/n, Lima-Perú.
[2] Universidad Nacional Agraria La Molina, Deparment of soils, Faculty of Agronomy, Thesis of Agricultural Engineer, Av. La Molina s/n, Lima-Perú.

*Corresponding author: lhurtado@lamolina.edu.pe
*https://orcid.org/0000-0002-5202-3971

Abstract

Peruvian cotton is recognized worldwide for its excellent quality, with the Tangüis and Pima varieties of long and extra-long fiber stand out as the ones with the best fiber quality and occupy the largest planting area. For this genetic potential to be expressed, adequate agronomic management is important, with fertilization being essential to achieving this objective; under this premise, a trial was installed in the Irrigation Research Unit of the Department of Soils of the Universidad Nacional Agraria la Molina (UNALM) in the 2021-2022 campaign. Two commercial varieties of Tangüis cotton were evaluated; MASSARO and UNA N°1 and a new variety MOLINERO EXTRA LARGO, obtained from the cross of Tangüis and Pima, testing three levels of nitrogen, phosphorus, and potassium fertilization, 80:40:80, 120:60:120 and 160:80:160 kg NPK/ha, and an unfertilized control. The statistical design was complete randomized blocks in factorial arrangement, with twelve treatments and 4 replications. Each treatment was installed in an experimental unit of 3.4m^2. This research was conducted in sandy loam soil, moderately saline, with low potential and basic fertility. The results show that NPK fertilization significantly affects the yield in the branch, fiber, number, and weight of the boll. The yield trend is linear, with a 46 % increase at 160:80:160 kg NPK/ha compared to the control. The response between varieties indicated that MOLINERO EXTRA LARGO had the highest yield of raw cotton (3589 kg.ha^{-1}) and fiber (1200 kg.ha^{-1}), different from UNA N°1 by 12 % and from MASSARO by 23 %. Regarding fiber quality, there was no significant response to fertilization. However, at the variety level, MOLINERO EXTRA LARGO produces the finest fiber, with a micronaire value of 4.2, the greatest uniformity (89.5 %), and the longest fiber length 39.8 mm, 6 % greater than UNA N° 1 and 19 % greater than MASSARO. Finally, UNA N°1 showed mean values in fiber quality between MOLINERO EXTRA LARGO and MASSARO, the latter is characterized by its higher resistance (33.6 g/tex) and lower fineness (5.3 micronaire).

Keywords: *Branch cotton, fiber, Molinero.*

How to cite this article:
Hurtado, L., & Cajacuri, G. (2024). NPK fertilization in the productive capacity and fiber quality of Tangüis Cotton (*Gossypium barbadense* L.). *Peruvian Journal of Agronomy, 8*(2), 90-101. https://doi.org/10.21704/pja.v8i2.1992

Resumen

El algodón peruano es reconocido a nivel mundial por su excelente calidad, destacando las variedades Tangüis y Pima de fibra larga y extralarga como las de mejor calidad de fibra y las que ocupan la mayor superficie de siembra. Para que este potencial genético se exprese es importante un manejo agronómico adecuado, siendo la fertilización fundamental para lograr este objetivo; bajo esta premisa, se instaló un ensayo en la Unidad de Investigación en Riego del Departamento de Suelos de la Universidad Nacional Agraria la Molina (UNALM) en la campaña 2021-2022. Se evaluaron dos variedades comerciales de algodón Tangüis; MASSARO y UNA N°1 y una nueva variedad MOLINERO EXTRA LARGO, obtenida del cruce de Tangüis y Pima, ensayando tres niveles de fertilización con nitrógeno, fósforo y potasio, 80:40:80, 120:60:120 y 160:80:160 kg NPK/ha, y un testigo sin fertilizar. El diseño estadístico fue de bloques completamente al azar en arreglo factorial, con doce tratamientos y 4 réplicas. Cada tratamiento se instaló en una unidad experimental de 3,4m^2. Esta investigación se realizó en suelo franco arenoso, moderadamente salino, con bajo potencial y fertilidad básica. Los resultados muestran que la fertilización NPK afecta significativamente el rendimiento en la rama, fibra, número y peso de la cápsula. La tendencia del rendimiento es lineal, con un incremento del 46 % a 160:80:160 kg NPK/ha en comparación con el testigo. La respuesta entre variedades indicó que MOLINERO EXTRA LARGO presentó el mayor rendimiento de algodón crudo (3589 kg.ha^{-1}) y fibra (1200 kg.ha^{-1}), diferente a UNA N°1 en 12 % y a MASSARO en 23 %. En cuanto a la calidad de la fibra, no hubo respuesta significativa a la fertilización. Sin embargo, a nivel de variedad, MOLINERO EXTRA LARGO produce la fibra más fina, con un valor de micronaire de 4,2, la mayor uniformidad (89,5 %), y la mayor longitud de fibra 39,8 mm, 6 % mayor que UNA N° 1 y 19 % mayor que MASSARO. Finalmente, UNA N°1 presentó valores medios en calidad de fibra entre MOLINERO EXTRA LARGO y MASSARO, este último se caracteriza por su mayor resistencia (33,6 g/tex) y menor finura (5,3 micronaire).

Palabras clave: *Algodón en rama, fibra, Molinero.*

Introduction

The Tangüis long-staple and extra-long-staple Pima cotton varieties are considered to be the finest vegetable fibers in the world. However, the national production of this crop has decreased significantly in Perú in recent years, due to the constant fall in international prices, competition with imported cotton, and because of the decrease in the areas planted with cotton, due to the installation of export crops (León, 2021). This, added to the serious drop in demand for cotton in the 2019-2020 campaign, due to the global economic recession, suggests that the recovery of this crop will take a few years. Therefore, it is necessary to continue with research to obtain new varieties and generate their respective technological package that will increase productivity and make cotton cultivation more competitive. Cotton yields in Peru are low and of variable quality, one of the causes is the lack of better genetic material and modern production technologies. For this reason, the Research and Social Projection Program in Cotton of the UNALM has begun agronomic tests with a new variety MOLINERO EXTRA LARGO. It is expected that UNALM's contribution to this important sector with this new variety, which has Tangüis and Pima parents, will exceed commercial Tangüis cultivars in the Peruvian market in production capacity and fiber quality. In this regard, Sotelo et al. (2022) report that cotton yields in Ecuador are low due to the lack of genetic material and production technologies. Therefore, the National Institute of Agricultural Research of Ecuador (INIAP) introduced from Brazil the BRS-336 variety, which was tested in the field under two plant densities, with a local variety DP-Acala 90, INIAP technology and conventional technology. They found that the introduced variety, BRS-336, behaved similarly in agronomic and productivity aspects to the local variety DP-Acala 90 and that the use of the integrated crop management program with INIAP technology was decisive in increasing yield with an average of 4508 kg.ha^{-1} of raw cotton, 11.2 % higher than conventional technology. The nutrient requirement in cotton varies according to the type of soil, climate, and variety (Nieves, 2021). The Universidad Nacional Agraria La Molina - UNALM, the Peruvian Cotton Institute - IPA and the National Institute of Agrarian Innovation - INIA at the Vista Florida Agricultural Experimental Station, have continued with the work of genetic improvement of cotton; however, greater efforts are needed and dissemination of agronomic technological packages to increase their productive capacity. One of the biggest problems to be solved is rational fertilization, according to the farmer's edaphic, climatic and technological conditions. Cotton cultivation has a high demand for macronutrients such as nitrogen, phosphorus, and potassium. Given its high productivity, it needs an abundant and rapid supply of nutrients (Távara, 2011). Nutrient deficiency reduces plant growth, yield, and fiber quality. Among all essential nutrients, nitrogen is the primary nutrient that restricts the growth of the cotton plant. Nitrogen fertilization, in addition to the adequate water regime, often promotes vegetative growth at the expense of reproductive growth. An increase in the production of raw cotton can be associated with nitrogen fertilization, since, as the fruiting period is extended, the number of floral positions on the fruit branches can be increased. Regarding fiber quality, nitrogen has a limited effect; it only marginally enhances fiber length and reduces micronaire by increasing the number of bolls. Nitrogen demand is directly related to bolls production. If the crop suffers from organ drop, it is necessary to reduce nitrogen applications, since excess N in a crop with few fruit organs causes a return to vegetative growth (Reyes, 2014).

A balanced supply of nitrogen determines the development of new meristems and the development and succulence of roots, stems, leaves, and seeds. As a result, it generates foliage with a deep green color, increases protein levels, and regulates potassium and phosphorus absorption (Marschner, 1997; Mengel & Kirkby, 2000). N is essential for crops in general, but it is important to observe an overuse of nitrogen fertilizers for environmental pollution problems (Dong et al., 2023).

On the other hand, phosphorus is the nutrient that after N contributes to obtaining high cotton yields. It should be borne in mind that the fixation capacity of many soils can delay the availability of this nutrient provided by fertilizer. Phosphorus is involved in processes such as photosynthesis, respiration, energy storage and transfer, cell division, and growth, among others. Phosphorus deficiency in the early stages of cultivation results in poor flower and seed formation and delayed ripening. Phosphorus uptake in the early stages of plant growth contributes to increased nitrogen utilization efficiency and also boosts root formation and growth (International Plant Nutrition Institute [IPNI], 2016). Finally, a severe deficiency results in small plants, with small and dark leaves, flowering is delayed and there is a severe reduction of fruiting organs and reduction of fiber length (Reyes, 2014).

Potassium plays an important role maintaining the plant's water status, the turgor pressure of its cells and the process of opening and closing the stoma. It is also required for the accumulation and translocation of newly formed carbohydrates (Jones, 1998). The applications of this nutrient in potassium-deficient soils can contribute to better yields, increase the number and weight of bolls, and improve the quality of the fiber by increasing the length, thickness, and resistance of the fiber and increasing the percentage of oil in the seed and likewise, confer more resistance to certain pests and diseases such as "wilt" or "fusarium". Its deficiency causes the presence of small bolls and smaller numbers (Reyes, 2014). Potassium is important for fiber development and quality. Its deficiency produces less fiber growth and less cellulose deposition in the secondary wall of the fibers, reducing strength, maturity, micronaire, elongation, length, perimeter, and uniformity, in addition, dead or immature fibers are produced, which do not color during the staining process (Cassman et al., 1989). In cotton, the direct effect of potassium deficiency on fiber quality was observed for the micronaire parameter with values below 3.5, which is expressed in the fiber cell, because it has a thin cell wall, with small amounts of cellulose. The addition of potassium increased metabolic processes associated with the thickening of secondary cell walls (Bradow & Davidonis, 2000).

The hypothesis of the study states that the response to high levels of NPK fertilization will determine significant increases concerning the unfertilized control in the productive capacity and fiber quality of the cotton varieties studied; MASSARO, UNA Nº 1, and MOLINERO EXTRA LARGO. The yield and quality of cotton fiber are influenced by various biotic and abiotic factors, which can negatively affect the growth and yield of the plant, causing economic losses to the producer (Prem Kumar et al., 2016).

The objective of this study was to evaluate the answer of the level of nitrogen, phosphorus, and potassium fertilization on the productive capacity and fiber quality of three varieties of cotton (*Gossypium barbadense* L.): MASSARO, UNA N° 1 and MOLINERO EXTRA LARGO, under central coast conditions, during the 2021-2022 campaign.

Materials and methods

The test was carried out during the 2021 - 2022 campaign, in the Irrigation Unit of the Academic Department of Soils of the UNALM, Latitude: 12° 05' 06 " South, Longitude: 76° 57", West Altitude: 238 m.a.s.l. Temperatures ranged from 8.4ºC to 28ºC and relative humidity averaged 79.3 %. The physicochemical characteristics indicate that the soil is sandy loam, with a moderately basic pH (7.8), the availability of NPK is variable, Nitrogen is limited, and phosphorus and potassium are at a medium level. The electrical conductivity of the saturation extract (5.8 dS/m) indicates moderate salinity (see soil analysis in Table 1), a relative problem in cotton cultivation due to its recognized resistance to salinity and its low sensitivity. to the increase in soluble salts. The genetic variation of cotton germplasm in morphological, physiological, and biochemical parameters allows for improved salinity tolerance (Chaudhary et al., 2024).

The low level of organic matter (0.71 %) indicates low availability of nitrogen. The cationic ratios for Ca/Mg = 4.0, for Ca/K = 20 and Mg/K = 4.9 show that in comparison to Ca and K, magnesium levels are very high, which may affect normal absorption of these elements. The irrigation water shows a neutral pH (7.1), irrigation water has an electrical conductivity of 3.2 dS/m, which makes it restrictive for most crops, except cotton, the alkalinity is low and it has a high nitrate concentration (0.81 meq/L) source important nitrogen for the crop, the presence of bicarbonates (2.25 meq/L) could generate clogging problems in emitters. (Cajacuri, 2024)

Table 1: Analysis of the soil used in the field phase

Característica	Valor	Clasificación
Sand (%)	64	-
Silt (%)	21	-
Clay (%)	15	-
Soil Texture		Sandy loam
pH en $H_2O_{(1:1)}$	7.52	moderately basic
Electrical Conductivity Ee (dS m^{-1})	5.6	Moderately saline
$CaCO_3$ (%)	3.43	Slightly chalky
Organic matter (%)	0.71	Very low
Available Phosphorus (mg kg^{-1})	22.5	Middle
Available Potassium (mg kg^{-1})	166	Middle
CIC ($cmol_c$ kg^{-1})	13.1	Low
Ca^{2+} ($cmol_c$ kg^{-1})	9.81	Middle
Mg^{2+} ($cmol_c$ kg^{-1})	2.42	High
K^+ ($cmol_c$ kg^{-1})	0.49	Low
Na^+ ($cmol_c$ kg^{-1})	0.41	Optimal
$Al^{3+} + H^+$ ($cmol_c$ kg^{-1})	0.0	-
PSB (%)	100	No hydrogen ions are found in colloids

Source: Water, Soil and Fertilizer Analysis Laboratory 202

In the present study, three varieties of cotton were tested; MASSARO variety, Tangüis from the Cañete lineage, LMG 2 – 95, grown in the valleys of Chincha and Pisco, highlights it's vigor and the good yield on the branch; variety UNA N° 1: Tangüis, obtained in the Cotton Research and Social Projection Program of the Universidad Nacional Agraria La Molina, highlights its precocity, vegetative period of 210 days on average and the new variety MOLINERO EXTRA LARGO, from Tangüis parents and Pima, obtained in the Cotton Program of the Universidad Nacional Agraria La Molina.

The three NPK fertilization levels tested in the three cotton varieties were, NPK_1: 80:40:80 $kg.ha^{-1}$, NPK_2: 120:60:120 $kg.ha^{-1}$, NPK_3: 160:80:160 $kg.ha^{-1}$, and a control unfertilized 0:0:0 $kg.ha^{-1}$ of NPK these fertilization levels were based on the recommendations of the Directorate of Fertilizers of the Ministry of Agriculture and Irrigation of Peru, that states to obtain approximately 3.6 tons of branch cotton it should be applied: 160:65:80 $kg.ha^{-1}$ of NPK (AGRO RURAL, 2018). It's important to note that the unfertilized control (NPK0) serves as a reference against which the effects of fertilizer treatments can be assessed. Comparing results to this baseline provides valuable information that can assist farmers in optimizing both the amount and type of fertilizers used. The statistical design was completely randomized blocks in a factorial arrangement of 12 treatments and four repetitions. The total area of the plot was 162 m^2, divided into 4 blocks in each of which the NPK fertilization levels were randomly distributed, in experimental units of 3.4 m^2.

Fertilization

The fertilization program began with the application of the phosphorus source, on four occasions, from the third week of cultivation, after the emergence of the plant, until the sixth week. The phosphorus fertilization levels were: 40 $kg.ha^{-1}$, 60 $kg.ha^{-1}$, and 80 $kg.ha^{-1}$ tested with a control not fertilized with Phosphorus. The fertilizer source was monoammonium phosphate, which was divided into four applications, all of which were the same. Each fraction of the phosphorus fertilizer was dissolved in 20 liters and applied directly to the irrigation line.

The application of nitrogen was carried out four times, it began when the plant entered the stem elongation phase, in the sixth week of crop development. The levels of nitrogen fertilization were 80 $kg.ha^{-1}$, 120 $kg.ha^{-1}$, and 160 $kg.ha^{-1}$, tested with a control not fertilized with nitrogen. The fertilizer source used was ammonium nitrate, which was divided into equal parts, in solution and one per week. The nitrogen fertilizer solution was applied to the row of plants in line with the irrigation lateral.

Regarding potassium fertilization, the application began in the flowering stage, from week eight to week eleven of the crop's development. The levels of potassium fertilization were 80 $kg.ha^{-1}$, 120 $kg.ha^{-1}$, and 160 $kg.ha^{-1}$, with a control not fertilized with potassium. The fertilizer source was potassium sulfate, which was divided into four parts. The application of the fertilizer was in solution, once a week, distributed in the row of plants in the line of the irrigation side.

After the application of nitrogen, phosphorus and potassium fertilizers, irrigation was carried out for 30 minutes (30.7 $m^3.ha^{-1}$) in order to incorporate the fertilizer solution into the middle part of the wet bulb. The irrigation program was established based on the calculation of the water needs of the cotton crop (mm per day per phenological phase) and determining the irrigation requirement ($m^3.ha^{-1}$) based on the efficiency of the system (uniformity coefficient: CU: 0.90), with the irrigation per cycle requirement being 4,034$m^3.ha^{-1}$

Results and discussion

Figure 1: MOLINERO EXTRA LARGO

Figure 2: UNA N°1

Figure 3: MASSARO

Productive capacity characteristics

Table 2 shows the response to NPK fertilization of three cotton varieties in their productive capacity. The trend in raw cotton yield and fiber yield is linearly increasing. In raw cotton, the highest average branch yield was with the highest level of NPK_3 fertilization 3889 $kg.ha^{-1}$, and the minimum yield occurred with the non-fertilized control NPK_0, 2657 $kg.ha^{-1}$. therefore, the highest yields are presented at the level of 160:80:160 $kg.ha^{-1}$ NPK, which is 46 % higher than the branch yield of the control. In the case of cotton fiber yield, the average of the three varieties with the highest level of NPK_3 fertilization is 1364 kg.ha^{-1} of fiber, this is 49 % more than the yield achieved with the non-fertilized NPK_0 control of 919 kg.ha^{-1}.

The components of performance; The number and weight of bolls per plant increase with increasing fertilization. The highest number of bolls in the trial was achieved with the highest NPK_3 level, 16.7 bolls per plant on average, this is 31 % more than the NPK_0 control with 12.9 bolls per plant on average. This is according to the hypothesis raised in this study, at high levels of NPK fertilization significant increases will be obtained concerning the control. In the case of the percentage of fiber, no significant differences were found between the different levels of fertilization, the values obtained fluctuated between 34.6 % with NPK_0 and 35.3 % with NPK_3.

Table 2, in the analysis section by variety, highlights that MOLINERO EXTRA LARGO has the highest values in raw cotton and fiber yield per ha, as well as the highest number and weight of acorns per plant; but the highest percentage of fiber occurs in MASSARO with 36.1 %. Figure 1 shows the trend of branch yield and fiber yield in kg.ha^{-1}.

The results obtained are in line with those reported by Cheng-Song (2010) from saline soils, it has the highest yield in branch and fiber; Likewise, Santana & Dos Santos (2008) found a significant response with 180 kg.ha^{-1} of nitrogen and applications of 60 kg.ha^{-1} of phosphorus and potassium.

In general, this results coincide with those found by Ahmad et al. (2023), who conclude that the use of NP has a positive impact on cotton growth and yield.

The positive response in branch yield is likely largely due to nitrogen fertilization since the soil in the present trial had a very low level of organic matter (0.71 %). With a high level of fertilizer, plants can extract more nutrients from the soil compared to a low level of fertilizer. Nutrient uptake rises with higher fertilizer levels, which may be associated with the accumulation and increased dry matter in the plant (Aruna et al., 2020)

The results on cotton fiber yield, agree with what was reported by Kappes et al. (2016) who found that cotton fiber yield was positively affected by nitrogen and potassium fertilization.

Figure 4. An increase in the yield of raw cotton and fiber cotton is observed. The level of NPK fertilization is increasing linearly. It stands out that for maximum NPK_3 fertilization (160:80:160 kg.ha^{-1} of NPK) the maximum yield is obtained, both for raw cotton (3889 kg.ha^{-1}) and for fiber cotton (1364 kg.ha^{-1}).

For raw cotton yield, the statistical analysis of interaction effects reveals significant results, the behaviour of UNA N°1 and MASSARO are similar, with yields at the NPK_3 (a) level of 4105 kg.ha^{-1} and 3509 kg.ha^{-1} respectively. These results are statistically different from NPK_2 (b), NPK_1 (c), NPK_0 (c). characterizing the lowest yield to the unfertilized control, NPK_0 with 2423 kg.ha^{-1} in MASSARO and 2655 kg.ha^{-1} in UNA

Table 2: Response of NPK fertilization on the productive characteristics of three cotton varieties

Fertilization Levels N-P_2O_5-K_2O kg.ha^{-1}	Branch yield (kg.ha^{-1})	Fiber yield (kg.ha^{-1})	Fiber percentage (%)	N° bolls /plant	Bolls weight (g)
NPK0 0 0 0	2657 D	919 D	34.6 A	12.9 D	5.0 D
NPK1 80 40 80	2986 C	1015 C	34.3 A	13.9 C	5.2 C
NPK2 120 60 120	3445 B	1192 B	34.7 A	15.4 B	5.4 B
NPK3 160 80 160	3889 A	1364 A	35.3 A	16.7 A	5.6 A
Cotton Varieties					
MOLINERO EXTRA LARGO	3589 A	1200 A	33.5 B	15.3 A	5.6 A
UNA N°1	3217 B	1106 B	34.5 B	14.2 B	5.4 B
MASSARO	2927 C	1062 B	36.1 A	14.7 B	4.8 C

Equal letters in the column indicate that there are no significant differences between the values (p > 0.05), according to Duncan's comparison of means test

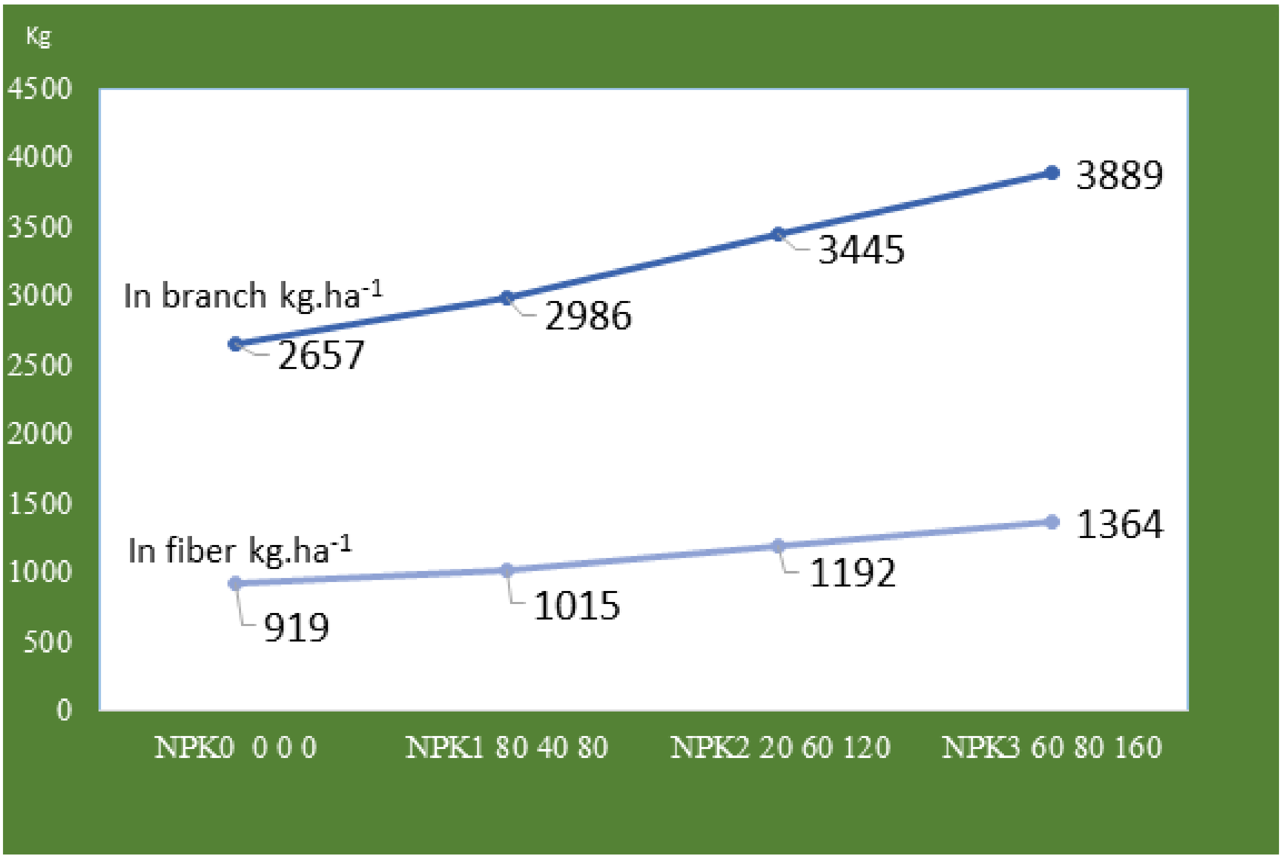

Figure 4: Comparison of yield of raw cotton and fibre kg.ha^{-1}

N° 1.

On the other hand, MOLINERO EXTRA LARGO presents branch yields that are statistically similar in NPK_1, NPK_2, and NPK_3 (a) but statistically different from the unfertilized control NPK_0 (b). This response is in line with the findings of other researchers who observed positive responses of cotton to low levels of fertilization (Pundarikakshudu, 1988) who found a positive response in yield with low applications of 40 kg.ha^{-1} of P and Palomo et al. (2003) who obtained significant cotton yield levels of 80 kg.ha^{-1}. These results are useful for the farmer since it seems that this variety would respond efficiently to low levels of fertilization.

In the case of the yield of cotton in fiber, the response is similar to the yield in the branch. The behaviour of UNA N°1 and MASSARO are statistically similar. The yield at the NPK_3 level differs from those achieved with lower NPK fertilization levels, with the lowest yield at the unfertilized control level. In the case of MOLINERO EXTRA LARGO there are significant differences in each level of NPK fertilization, with the highest value being 1336 kg.ha^{-1} of fiber (a) at the NPK_3 level and the lowest at the level of the unfertilized NPK_0 control with 1009 kg.ha^{-1}. This is in line with some of the findings of Wang et al. (2021) who observed high fiber yield with a level of 250:43.7:41.5 kg.ha^{-1} of NPK.

On the other hand, the analysis of the interaction effects of the fiber percentage gave significant results at the NPK level in the MASSARO variety. The comparison of means indicates that at the NPK_3 and NPK_2 levels the fiber percentages are similar, but different from the unfertilized control that has the lowest fiber percentage with 34.4 %. Likewise, MASSARO presented an increasing response with the increase in the level of NPK fertilization, which coincides with Saleem et al. (2010), who found that at the level of 120 kg.ha^{-1} of N the highest percentage of fiber was present. On the other hand, MOLINERO EXTRA LARGO's response coincides with Reyes (2014), who concludes that there is no positive effect of increasing nitrogen fertilizer on the percentage of fiber. It is also observed that the effect of NPK fertilization on the fiber percentage of the UNA N°1 variety agrees with what was cited by Basurto (2004), in the sense that the fiber percentage shows constant values for each cotton variety.

Regarding the variable number of bolls, the behaviour of UNA N°1 and MASSARO was statistically similar. The number of bolls at the NPK_3 level, with 17 acorns per plant in both varieties, differ statistically from those achieved with lower levels of NPK fertilization. The lowest number of bolls per plant characterizes the unfertilized control NPK_0. MASSARO with 13 bolls and UNA N° 1 with 12 bolls per plant. In the MOLINERO EXTRA LARGO variety, the responses are statistically similar for NPK_1, NPK_2, NPK_3, which has 16 bolls per plant. These results coincide with what was stated by Reyes (2014), in the sense that by increasing fertilization levels appropriately on all the nitrogen, vegetative growth is favored, which generates more points of growth of reproductive organs. This is in line with what Thakur (2020) found, which had a significant response with the dose 75:37.5:37.5 $kg.ha^{-1}$ of NPK that positively influenced the growth and weight of bolls.

However, it should be noted that the low temperature at the boll development stage (13 °C) may have influenced the decrease in the number of bolls. In the boll weight variable, there are highly significant differences between NPK fertilization levels and varieties. The interaction effects were not significant. The highest boll weight is observed at the NPK_3 level with 5.6 g, which represents an increase of 12.8 % compared to the unfertilized control NPK_0 with 5 g per boll. Likewise, the comparison of cotton varieties indicates that MOLINERO EXTRA LARGO presented the highest boll weight with 5.6 g, UNA N"1 with 5.4 g, and MASSARO with 4.8 g of boll weight.

Cotton fiber quality characteristics

Table 3 presents the response of nitrogen, phosphorus, and potassium fertilization on the fiber quality of three varieties of cotton. Due to the effect of NPK fertilization, there are no significant differences in length (mm), fiber resistance (g/tex), and uniformity (%). However, there is an increasing trend in fiber length (mm) with increasing levels of NPK, with the longest length being 37.4 mm of the three varieties under NPK_3 and the shortest length being 36.7 mm under the NPK_0 unfertilized control level and at the variety level, the longest length was 39.8 mm of MOLINERO EXTRA LARGO.

The greater uniformity characterizes the NPK_3 fertilization level with 88.9 %, with an increase of 1 % compared to the unfertilized NPK_0 control with 88.1 % uniformity. In the case of the results in fiber resistance, 33.5 g/tex is recorded on average of the three varieties at the NPK_3 level, and the lowest fiber resistance was presented at the level of the unfertilized control NPK_0 with 32.7 g/tex.

Only in the fineness characteristic, are statistical differences ($p<0.05$) presented for

Table 3: Response of NPK fertilization on the fiber quality of three varieties of cotton

Fertilization Levels $N\text{-}P_2O_5\text{-}K_2O$ $kg.ha^{-1}$	Length (mm)	Strength (g/tex)	Fineness (micronaire)	Uniformity (%)
NPK0 0 0 0	36.7 A	32.7 A	4.9 A	88.1 A
NPK1 80 40 80	36.7 A	33.0 A	4.8 BA	88.2 A
NPK2 120 60 120	37.1 A	33.1 A	4.7 B	89.0 A
NPK3 160 80 160	37.4 A	33.5 A	4.7 B	88.9 A
Cotton Varieties				
MOLINERO EXTRA LARGO	39.8 A	32.6 A	4.2 C	89.5 A
UNA N°1	37.7 B	33.0 BA	4.8 B	88.5 B
MASSARO	33.3 C	33. 6 B	5.3 A	87.7 B

Equal letters in the column indicate that there are no significant differences between the values ($p > 0.05$), according to Duncan's comparison of means test.

NPK fertilization levels and cotton varieties highly significant statistical differences ($p<0.01$). The highest fineness was with NPK_3 with a value of 4.9 micronaire on average of the three varieties and the minimum 4.7 micronaire with the unfertilized control NPK_0, and at the variety level is MOLINERO EXTRA LARGO which presents the highest fineness 4.2 micronaire on average.

Regarding these results, Reyes (2014) indicates that at increasing rates of nitrogen and potassium application, increases in fiber length are observed. Likewise, Pervez (2005) observed that fiber length increased with the addition of potassium significantly. The findings differ from Rashidi & Gholami (2011) who observed that nitrogen application was not significant for fiber fineness, in the same way Saleem (2010) found that nitrogen fertilization did not show significant effects on fiber quality.

On the other hand, the comparison between cotton varieties presents differences in quality characteristics. MOLINERO EXTRA LARGO, has the longest length (39.8 mm), the finest fiber with 4.2 micronaire, the greatest uniformity (89.5 %), and the least resistance. The MASSARO variety is characterized by the shortest length (33.3 mm) and the fiber of less fineness with 5.3 micronaire. Regarding the UNA N° 1 variety, it shows intermediate values in all quality characteristics, similar in strength and fiber uniformity with MASSARO. Palomo et al. (2004), conducted research with Mexican cotton varieties, testing the response to the application of increasing levels of nitrogen, and found a significant response in fiber percentage, seed index, and fiber resistance. Likewise, the best percentages of fiber were presented with the unfertilized control and the best seed indices and the highest fiber resistance was presented at the level of 160 $kg.ha^{-1}$ of nitrogen. Nitrogen, phosphorus and potassium are nutrients that condition the establishment and maintenance of the photosynthetic capacity of the leaves. Nitrogen, especially promotes vegetative growth, increases the total number of flowers and shoots, and increases the size of acorns due to the greater individual weight of the seeds. They also play an important role in cotton development and together with potassium, determine the quality of fiber (Scarpin et al., 2016).

Bonilla et al., (2020) indicated that the length, resistance and fineness of the cotton fiber are due more to genetic factors than environmental factors such as soil quality, temperature, rainfall, management, etc. Despite this, it is necessary to continue research since it is the largest source of natural fiber. Its development process is of crucial importance (fibers originated from ovular epidermal cells), and it is necessary to better understand the general mechanisms to know its development (Tian & Zhang, 2021).

Conclusions

The increasing level of NPK fertilization positively affected the productive capacity (raw cotton and fiber yield) of the three cotton varieties. Under the test conditions the branch yield of raw cotton, with the highest NPK treatment, is 46 % higher than the branch yield of the control.

The new variety MOLINERO EXTRA LARGO shows a greater productive capacity. It increases by 12 % concerning the UNA N°1 variety and 23 % concerning the MASSARO variety, with a greater number and more weight of bolls.

The increasing level of NPK fertilization in the three cotton varieties did not significantly affect the fiber quality; however, there are significant differences in the responses of each variety. The greater fiber length, greater uniformity, and fineness were presented in the MOLINERO EXTRA LARGO variety. The highest strength, but the lowest fiber fineness was observed in the MASSARO variety. The UNA N° 1 variety had intermediate values.

Recommendations

Given the results, it is recommended to continue with studies that allow us to know the behavior of the new variety MOLINERO EXTRA LARGO, under the effect of other doses of NPK fertilization, fertilization with calcium, and microelements such as iron, manganese and zinc of low availability should be included in conditions of basic reaction soils.

Given the results, it is recommended to study the new variety MOLINERO EXTRA LARGO in different irrigation regimes, planting periods, and different geographical areas, to check its agronomic adaptability.

Acknowledgments

Academic Department of Soils of the Faculty of Agronomy of the Universidad Nacional Agraria La Molina.
Cotton Research and Social Projection Program of the Universidad Nacional Agraria La Molina.

Authors contributions

GCM: Conducted the field trial, data analysis, and interpretation of results and manuscript; LHL: Designed and supervised the field trial, analyzed the trial results, and corrected the manuscript.

Conflict of interest

There is no conflict of interest

Funding declaration

This work did not receive any funding, the resources belonged to the authors.

ORCID and e-mails

Lorenzo Hurtado Leo	lhurtado@lamolina.edu.pe
	https://orcid.org/0000-0002-5202-3971
Giovanna Cajacuri Moreno	cajacurigiovanna@gmail.com
	https://orcid.org/0009-0002-4081-6146

References

Ahmad, W., Saba, T., Butt, B., Jamil, M., Amin, F., Hayat, M., Akhtar, N., Jamil, S., Muslim, N., Shah, S., & Ayyoub, M. (2023). Comparative effect of different NPK fertilizers on growth of cotton (*Gossypium hirsutum* L.) in alkaline calcareous soil. 2023. *Journal of Plant and Environment, 5*(1), 29–33. https://esciencepress.net/journals/index.php/JPE/article/view/4584

Aruna B., Bhat, S. N., Balanagoudar, S. R., Vishwanath, J., & Anand, N. (2020). Uptake pattern of nutrients and yield of Bt Cotton as influenced by different nutrient management practices in a vertisol. *Int J Chem Stud, 8*(1), 2854–2858.https://www.chemijournal.com/s/?year=2020&vol=8&issue=1&ArticleId=8702&si=false

Agro Rural (2018). *Manual de Abonamiento con Guano de las Islas, Dirección de Abonos*. diciembre 2018. Programa de Desarrollo Productivo Agrario Rural. https://www.agrorural.gob.pe/wp-content/uploads/transparencia/dab/material/MANUAL%20DE%20ABONAMIENTO%20CON%20G.I..pdf

Basurto, C. (2004). *Caracterización morfológica y molecular de 7 genotipos de algodón*. [Tesis de pregrado, Universidad Nacional Agraria La Molina].

Bonilla, O., Hernández, E., Verastegui, J., Maltos, J., Bautista, E., Hernández, A., & Isidro-Requejo, L. (2020). Productividad y calidad de fibra de variedades convencionales de algodón en la Comarca Lagunera, México. *Rev. fitotec. Mex*., *43*(1). https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0187-73802020000100003

Bradow, J. M., & Davidonis, G. H. (2000). Quantitation of fiber quality and the cotton production-processing interface: a physiologist´s perspective. *Journal of Cotton Science*, *4*, 34–64.

Cajacuri, G. (2024). Nivel nutricional en la capacidad productiva y calidad de fibra de algodón Tangüis *(Gossypium barbadense L.)* [Tesis de pregrado, Universidad Nacional Agraria La Molina]. http://repositorio.lamolina.edu.pe/handle/20.500.12996/6196

Cassman, K. G., Kerby, T. A., Roberts, B. A., Bryant, D. C., & Brouder, S. M. (1989). Differential response of two cotton cultivars to fertilizer and soil potassium. *Agronomy Journal. 81*, 870–876.

Chaudhary, M., Majeed, S, Rana, I., Ali, Z., Jia, Y., Du, X., Hinze, L., & Tehseen, M. (2024). Impact of salinity stress on cotton and opportunities for improvement through conventional and biotechnological approaches. *BMC Plant Biol 24*, 20. https://doi.org/10.1186/s12870-023-04558-4

Cheng-Song, X. (2010). Effects of N, P, and K Fertilizer Application on Cotton Growing in Saline Soil in Yellow River Delta. *Acta Agronomica Sinica, 36*(10), 1698–1706. https://www.sciencedirect.com/science/article/abs/pii/S187527800960078X

Dong, Z., Liu, Y., Li, M., Fen, X., Wen, S. & Ma, F. (2023). Effect of different NPK fertilization timing sequences management on soil-petiole system nutrient uptake and fertilizer utilization efficiency of drip irrigation cotton. *Sci Rep, 13*, #14287. https://www.nature.com/articles/s41598-023-40620-9

International Plant Nutrition Institute. (2016). *Soil Fertility Manual. International Plant Nutrition Manual*. Peachtree Corners, GA, US.

Jones, J. B. (1998). *Plant Nutrition*. CRC Press. Florida. USA. 140p.

Kappes, C., Zancanaro, L., & Bohac, E. (2016). Nitrogen and Potassium in Narrow-Row Cotton. *Revista Brasileira de Ciencia do Solo*, *40,* e0150103 https://www.scielo.br/j/rbcs/a/8RxJz9wCSWMkvzNfXchFBQz/?format=pdf&lang=en

León, C. (2021). *Área de algodón para la campaña 2020/2021.* Agencia Agraria de Noticias. https://agraria.pe/noticias/area-de-algodon-para-la-campana-2020-2021-disminuiria-en-8-m-23401

Marschner, H. (1997). *Mineral nutrition of higher plants*. Academic Press Inc. Londres, Gran Bretaña. 674p.

Mengel, K., & Kirkby, E. (2000). *Principles of Plant Nutrition*. 4ta. Ed. International Potash Institute. Berna. Suiza. 593 p.

Nieves, M. (2021). Manejo agronómico del cultivo de algodón en la Región Lambayeque. INIA Perú. https://www.youtube.com/watch?v=EryaP4DitRs&t=4444s

Palomo, A., Gaytán, A., & Godoy, S. (2003). Rendimiento, componentes del rendimiento y calidad de fibra del algodón en relación con la dosis de nitrógeno y la densidad poblacional. *Rev. Fitotecnia. Universidad Autónoma Agraria. México*, *26* (3), 167–171. https://revistafitotecniamexicana.org/documentos/26-3/6r.pdf

Palomo, A., Gaytán-Mascorro, A., Faz-Contreras, R., Reta-Sánchez, D., & Gutiérrez-del Río, E. (2004). Rendimiento y calidad de fibra de algodón en respuesta al número de riegos y dosis de nitrógeno. *Terra Latinoamericana*, *22*(3), 299–305. https://www.redalyc.org/pdf/573/57322306.pdf

Pervez, H., Ashraf, M., & Makhdum, I. (2005). Effects of Potassium rates and sources on fiber quality parameters in four cultivars of Cotton grown in Aridisols. *Journal of Plant Nutrition*, *27*(12), 2235–2257. https://n9.cl/elohj

Pundarikakshudu R 1988. Studies of the phosphate dynamics in a vertisol in relation to the yield and nutrient uptake of rainfed cotton, *Central Institute for Cotton Research,* India. https://doi.org/10.1017/S0014479700016422

Prem Kumar, G., Sivakumar, S., Siva, G., Vigneswaran, M., Senthil Kumar, T., & Jayabalan, N. (2016). Silver nitrate promotes high-frequency multiple shoot regeneration in cotton (*Gossypium hirsutum* L.) by inhibiting ethylene production and phenolic secretion. In Vitro Cellular and Developmental Biology. *Plant*, *52*(4), 408–418. https://doi.org/10.1007/s11627-016-9782-5

Rashidi, M., & Mohammad, *G.* (2011). Response of yield and yield components of *Cotton* to different rates of nitrogen fertilizer. *Academic Journal of Plant Science, 4*(1), 22–25. https://www.idosi.org/ajps/4(1)11/5.pdf

Reyes, P. (2014). *El Algodón Pima Peruano: Cultivo y manejo agronómico.* Universidad Nacional de Piura. Primera edición: Piura, septiembre de 2014. https://www.studocu.com/row/document/s-baischev-aktobe-university/introduction-to-programming-adv/libro-algodon-manejo-de-algodon/56899699

Santana, M., & Dos Santos, F. (2008), *Adubação do algodoeiro com* NPK *em sistema plantio direto no Cerrado*. VII Congresso Brasileiro do Algodão, Foz do Iguaçu, PR – 2009, pp. 2136. https://ainfo.cnptia.embrapa.br/digital/bitstream/item/64134/1/Adubacao-algodoeiro.pdf

Saleem, M. F., Bilal, M. F., Awais, M. M., Shahid, M. Q., & Anjum, S. A. (2010). Efecto del nitrógeno en el rendimiento de las semillas de algodón y en la calidad de la fibra de las variedades de algodón (*Gossypium hirsutum* L.). *Journal of Animal and Plant Sciences*, *20*, 23–27. https://www.thejaps.org.pk/docs/20-1-2010/Saleem_et_al.pdf

Scarpin, G., Venturini, L. M., & Paytas, M. (2016). Evaluación de la fertilización complementaria en dos variedades de algodón. *Voces y Ecos*, *26*, (36), 8–11. https://repositorio.inta.gob.ar/bitstream/handle/20.500.12123/15754/INTA_CRSantaFe_EEAReconquista_Scarpin_G_Evaluacion_fertilizacion_complementaria_variedades_algodon.pdf?sequence=1&isAllowed=y

Sotelo, A., Cañarte-Bermúdez, E., Zambrano-Gavilanes, F., Navarrete-Cedeño, B., & Suárez-Duque, D. (2022). Respuesta de la variedad de algodón BRS-336 a un programa de manejo bajo las condiciones de Manabí-Ecuador. *Revista Ciencia UNEMI*, *15*(38), 34–48. https://repositorio.iniap.gob.ec/handle/41000/5998

Távara, A. (2011). Manual de Manejo Integrado del cultivo del Algodonero – Modulo 1. Instituto Nacional de Innovación Agraria, Lima – Perú. https://repositorio.inia.gob.pe/bitstream/20.500.12955/750/1/T%C3%A1vara-Manejo_integrado_cultivo_algodonero.pdf

Thakur, M. (2020). Square formation, boll retention, yield and quality parameters of Bt and non Bt cotton in relation to plant density and NPK levels. International Journal of Chemical Studies. https://doi.org/10.22271/chemi.2020.v8.i1ap.8685

Tian, Y., & Zhang, T. (2021). MIXTAs and phytohormones orchestrate cotton fiber Development. 59, #101975 https://www.sciencedirect.com/science/article/abs/pii/S1369526620301187

Wang, H. Wu, L. Wang, X. Zhang, S. Cheng, M. Feng, H. Fan, J. Zhang, F. & Xiang, Y. (2021). Optimization of water and fertilizer management improves yield, water, nitrogen, phosphorus, and potassium uptake and use efficiency of cotton under drip fertigation, *Agricultural Water Management, 245,* #106662. https://www.sciencedirect.com/science/article/abs/pii/S037837742032206X