Revista Mexicana Ciencias Agrícolas volume 11 number 6 August 14 - September 27, 2020

Article

Production, growth and nutritional quality of chickpea depending on nitrogen and phosphorus

Maricela Apáez Barrios[1]
José Alberto Salvador Escalante Estrada[2]
Patricio Apáez Barrios[1§]
Juan Carlos Álvarez Hernandez[3]

Michoacán University of San Nicolás de Hidalgo-Faculty of Agricultural Sciences. Street Mariano Jiménez s/n, Colonia Varillero, Constitution Apatzingán, Michoacán de Ocampo, Mexico. CP. 60160. (mary-230488@hotmail.com). [2]Postgraduate College-*Campus* Montecillo. Mexico-Texcoco Highway km 36.5, Montecillo, Texcoco, State of Mexico, Mexico. CP. 56230. (jasee@colpos.mx). [3]Valley of Apatzingán Experimental Field-INIFAP. Highway Apatzingán-Cuatro Caminos km 17.5, Antúnez, Parácuaro, Michoacán, Mexico. CP. 60781. (alvarez.juan@inifap.gob.mx).

[§]Corresponding author: patrick280485@gmail.com.

Abstract

Chickpea is rich in protein and carbohydrates, of importance in human food. Currently, its performance is limited due to a lack of recommendations on fertilization, mainly nitrogen (N) and phosphorus (P). In this sense, these nutrients can contribute to increase yield, accelerate growth, biomass accumulation and nutritional quality. The objectives of the study were to evaluate the effect of N and P on the days to occurrence of phenological phases, grain yield, crop growth, biomass accumulation and nutritional quality of chickpea. Under seasonal rain conditions in Huitzuco, Guerrero, Mexico, chickpea was planted on June 1, 2017, with three levels of N (0, 75 and 150 kg N ha^{-1}) and P (0, 75 and 150 kg N ha^{-1}); respectively. During the study, the maximum and minimum temperatures ranged from 31 to 35 °C and 16 to 18 °C respectively, with rainfall of 806 mm. The occurrence of phenological stages was similar between treatments, thus, emergence occurred 10 days after sowing (dds), flowering at 55 dds and at 120 dds physiological maturity. With 150 kg of N and P ha^{-1} (N150-P150), the highest grain yield was presented (580 g m^{-2}), the highest accumulation of total biomass (490 g m^{-2}), and the grain was the organ of the plant to which the amount of accumulated biomass was modified with an increase of 3% in relation to treatments without N. The average growth rate of the crop was higher with applications of N, while with P the trend was similar. On the other hand, the nutrient that most influenced to intercept radiation was N. With N and P, the concentration of proteins and soluble carbohydrates increased mainly.

Keywords: *Cicer arietinum* L., proteins, yield.

Reception date: May 2020
Acceptance date: August 2020

Introduction

Chickpea (*Cicer arietinum* L.) is one of the crops with the highest protein content and economic importance, making it fifth in the world, where India contributes 75% of production, followed by Turkey, Pakistan and Mexico, the latter occupies the second place as an exporter and the third in production (FAOSTAT, 2019; SIAP, 2019).

According to Grelda *et al*. (1997), chickpea contains on average 69% carbohydrates, 5.3% fatty acids, 3.9% fiber and 18% protein in total nitrogen. Kaur (2005) mentions that chickpea, in addition to being an important source of protein and carbohydrates, also provides minerals such as Ca, Mg, Zn, K, Fe and P, as well as thiamine and niacin. Furthermore, starch is the most important carbohydrate in chickpea grain and is considered a competitive food in the food industry (Goñi and Gamazo, 2003). In addition to the above, there are different types of crop management that contribute to increasing production, the most important is to improve nutrition.

In this sense, it is necessary to determine the most appropriate dose of fertilization source that mainly includes nitrogen and phosphorus, nutrients most demanded by the plant (Olaleye *et al*., 2011), when these elements are provided in appropriate amounts, greater total biomass production is favored, increase the yield, number of pods and number of seeds per pod and there is even research that shows that by applying these nutrients the nutritional quality could be increased, mainly protein, which would lead to having a food that contributes a higher percentage with the good eating dish, thus being able to substitute animal protein (Aguilar *et al*., 2005). The same author mentions that the increase in performance is the result of intercepted radiation and this in turn of the size of the plant canopy, which represents the photosynthetic machinery. They also favor an increase in the leaf area and its duration, a consequence of greater leaf lamina growth (Escalante and Rodríguez, 2011; Escalante *et al*., 2014).

The growth analysis is very useful to understand the physiological causes that determine the grain yield due to the effect of fertilization. In addition, it is necessary to quantify important aspects such as the speed with which the crop grows, duration of the vegetative cycle, efficiency in the production of biomass, production speed of it in each phenological phase of the crop and its distribution in each organ of the plant. For the aforementioned, indices are used, such as the average growth rate of the crop (TCC). In addition, these measurements are helpful in improving understanding of the relationships between source and demand, since TCC estimates the rate of dry matter production per unit area planted per unit time.

Escalante, (1999) reports that the greater growth of the plant canopy increases the interception of light, which increases photosynthesis and therefore the production of total biomass. On the other hand, the investigations that are carried out at present are focused on the effect of the environment, management in the growth and development of the crop, where it is sought to increase the yield, the above merits evaluating the composition and nutritional quality of said legume. These types of technologies, in addition to increasing production mainly of grain, can improve nutritional quality, by increasing protein concentration and lowering fiber content mainly (Galal *et al*., 2010; Kozera *et al*., 2013).

Therefore, in this work, the study and knowledge of the proximal composition of the chickpea grain is important, since it is the organ of agronomic interest, in order to quantify the effect of the dose of nitrogen (N) and phosphorus (P), respectively. Thus, the objectives of the present investigation were to evaluate the effect of the dose of N and P on: a) the days to occur of the phenological stages, yield, biomass accumulation, average growth rate of the crop, intercepted radiation and b) quality nutritious of chickpea grain.

Materials and methods

The study was established in Huitzuco, Guerrero., Mexico (18° 15’ N, 99° 09’ W and 1 086 m altitude). The climate of the region is identified as AW_1 (w) (i) g, which corresponds to warm sub-humid with rains in summer. The chickpea genetic material was regional creole white. On June 1, 2017, the population density of 15 plants m^{-2} was planted. The treatments consisted of the application of 0, 75 and 150 kg of N and P ha^{-1} (N0, N75 and N150; P0, P75 and P150, respectively). The combination of N and P_2O_5 generated nine treatments. All the P and half of N were applied at 20 days after sowing (dds) and the rest at 45 dds. The sources used were ammonium sulfate (20.5% N) and triple calcium superphosphate (46% P).

The experimental design was randomized blocks arranged in divided plots with four replications. During the crop cycle the maximum temperature (Tmax, °C) and minimum (Tmin, °C) and accumulated precipitation (mm) were recorded, the data were obtained from the 12115 Huitzuco (DGE)-GRO weather station (18° 30’ north latitude and 99° 32’ west longitude). The phenological phases were also recorded, which were: days to emergence (E), to beginning of flowering (R1), beginning of fruiting (R2), end of fruiting (R3). To obtain the chickpea yield (RG, g m^{-2}), the harvest was performed at 120 dds.

The total biomass (BT, dry matter g m^{-2}) of each plant organ (stems, leaves, leaflets and grain) was also recorded. For this, the samples were dried at 75 °C in a forced air oven to constant weight. With these data, the absolute growth rate (TCC) was calculated, for the same periods (25.50, 75 and 100 dds), using the equation: $TCC= [(PS_2-PS_1) / (T_2-T_1)]$, where: PS_2 and PS_1 indicate the dry weight of the plant at times T_2 and T_1 respectively (Hunt, 1990).

To estimate the intercepted radiation (IR) by the plant canopy for 25, 50, 75 and 100 dds, the following equation was used: $IR= RFA (1-e^{-k*IAF})$, where RFA is the photosynthetically active radiation incident in the canopy (MJ m^{-2}), e= exponential, -k= light extinction coefficient. A regression analysis was also performed to determine the relationship between biomass production and IR.

The nutritional quality of the chickpea grain (minerals, soluble carbohydrates, proteins, fats, crude fiber, acid detergent fiber (FDA), neutral detergent fiber (FDN), hemicellulose, lignin and silica, all in%) was determined by chemical analysis proximal (Sosa, 1979), in the animal nutrition laboratory of the zootechnics department of the Autonomous University Chapingo (UACH). Previously, the dried chickpea grain samples were crushed in an electric mill (Janke and Kunkel Inka Model Kb 5/10®, Germany) with a 50 µm sieve.

The variables were statistically analyzed with the SAS version 9.0 package and the Tukey mean comparison test at 5% probability was applied to the differences between treatments (SAS, 2003).

Results and discussion

Climate and phenology

In Figure 1, which shows the maximum temperature (Tmax), minimum temperature (Tmin) (10-year average) and seasonal precipitation (10-year sum), it is observed that during the cultivation cycle the Tmax ranged between 31.3 and 35.8 °C and Tmin between 16.1 to 18.2 °C. The highest Tmax occurred in the first ten after emergence (E), while the lowest Tmin occurred in the ten 12. Total accumulated precipitation from planting (S) to physiological maturity (RH) was 806 mm, of which, 458 mm (56%) occurred from S to the beginning of fruiting (R2).

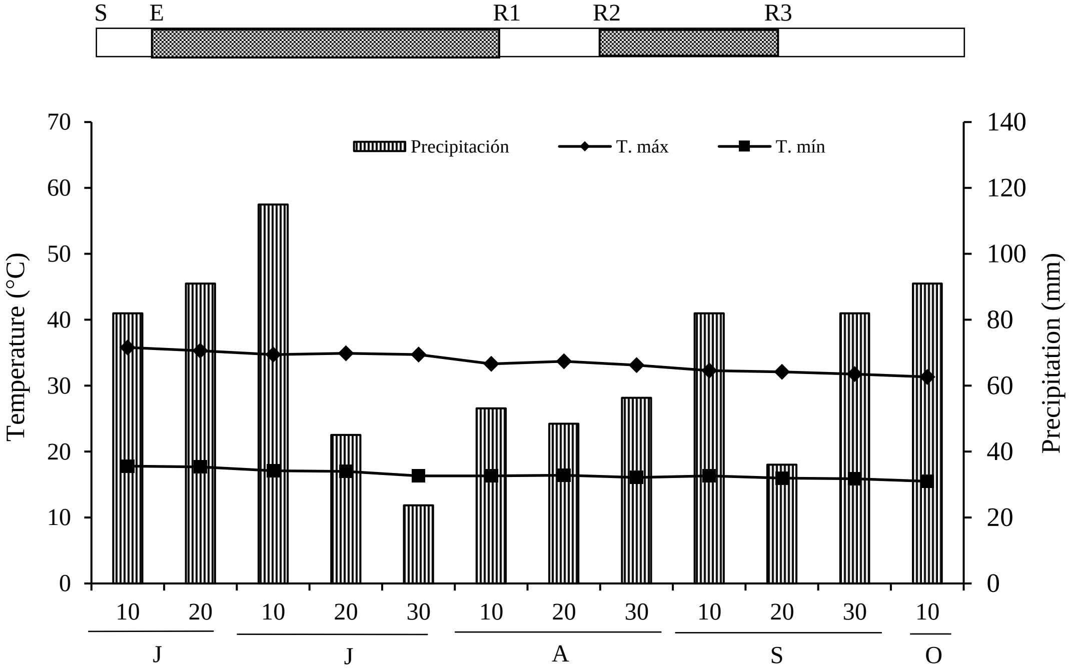

Figure 1. Maximum, minimum temperature (average 10-year) and precipitation (10-year sum) during the chickpea cultivation cycle and occurrence of phenological phases. S= sowing; E= emergency; R1= start of flowering; R2= beginning of fruiting; R3= end of fruiting and RH= physiological maturity. J= June; J= July; A= August. Huitzuco, Guerrero. Summer 2017.

According to Bejiga and Van Der Maesen (2006) the climatic conditions of both temperature and precipitation occurred in this study were appropriate for chickpea cultivation since the appropriate temperature range is from 10 to 25 °C with an optimum of 20 °C. The occurrence of the phenological phases was similar between treatments. Thus, emergence (E) appeared ten days after sowing (dds), start of flowering (R1) and 55 dds, end of fruiting (R3) at 100 dds and physiological maturity (RH) at the 120 dds (Figure 1).

A similar response is reported by Apáez *et al*. (2016) where the occurrence of the phenological phases was not modified by the effect of nitrogen application. Contrasting results have already been reported in other legumes such as beans, where according to Abayomi *et al*. (2008), with application of N and P, the cultivation cycle was reduced by 6 days.

Grain yield

The grain yield (RG) presented significant changes due to the effect of N and P (Figure 2) and the N $*$ P interaction (Figure 3). The highest RG was achieved with the highest level of N (N150), whose increase is 44% in relation to the control (N0). Regarding P, the high dose (P150) generated an increase of 59% in relation to the control (P0).

Regarding the combined effect, N150-P150, followed by N75-P150 and N75-P150, which allowed increasing the RG in relation to N0-P0 by 450, 410 and 403 g m^{-2} (Figure 2). The higher RG with N150 is attributed to the fact that the application of this nutrient delays leaf senescence, with which the duration of the leaf area is greater and therefore the production of photosynthates increases and a higher yield is generated (Escalante *et al*., 2014).

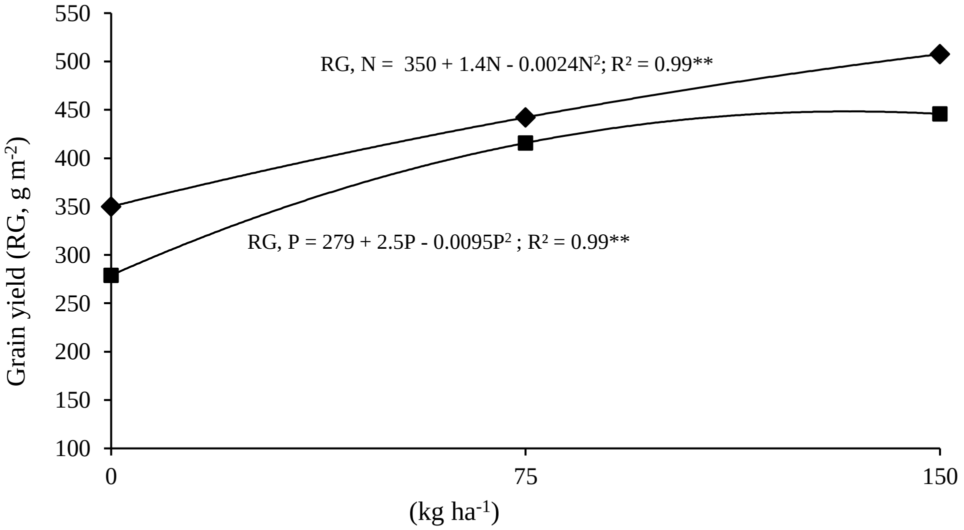

Figure 2. Grain yield (RG) of chickpea for main factors: nitrogen (N) and phosphorus (P). Huitzuco, Guerrero. Summer 2017.

On the other hand, Caliskan *et al*. (2008), indicate that this nutrient increases the rate of photosynthates and chlorophyll pigments and therefore the leaf area. With the above, a better use of water by the plant is achieved, this is important under seasonal rain conditions where this resource is limiting. Furthermore, by having a larger leaf area, the use of solar radiation is more efficient (García *et al*., 2002). Regarding the effect of P, Muhammad *et al*. (2008), report that the addition of P generates greater leaf area in crops such as soybeans, chinese beans and mung.

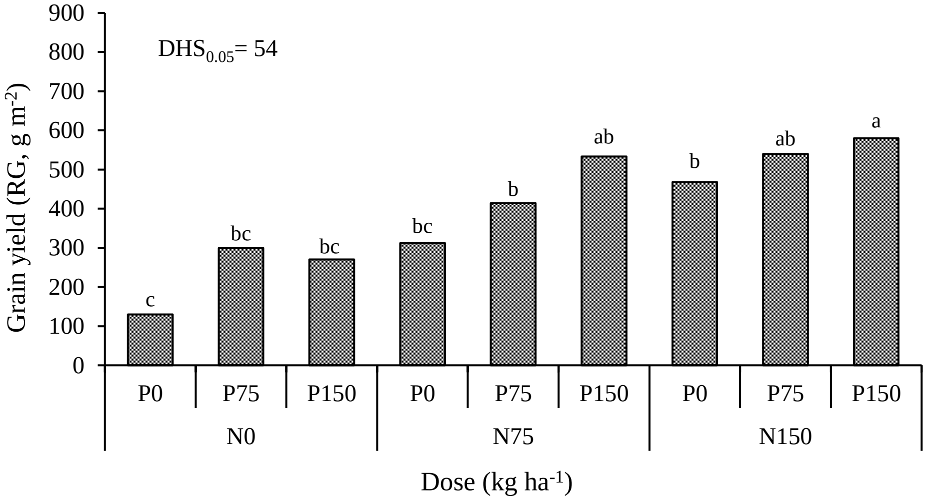

Figure 3. Grain yield (RG) of chickpea as a function of the combined effect of nitrogen (N) and phosphorus (P). $DSH_{0.05}$= honest significant difference at 5% probability. Huitzuco, Guerrero. Summer 2017.

Total biomass and its distribution in the plant

The total biomass production (BT) presented significant changes due to the effect of N, P and the N ∗ P interaction, while the distribution to the plant organs was only affected by N (Figure 4). The highest BT was generated with N75-P150 and N150-P150, with increases of 26 and 45% compared to the control (N0-P0). A similar response was found by Bernal *et al*. (2007) in common beans found increases of 46 to 66% in BT with phosphorus.

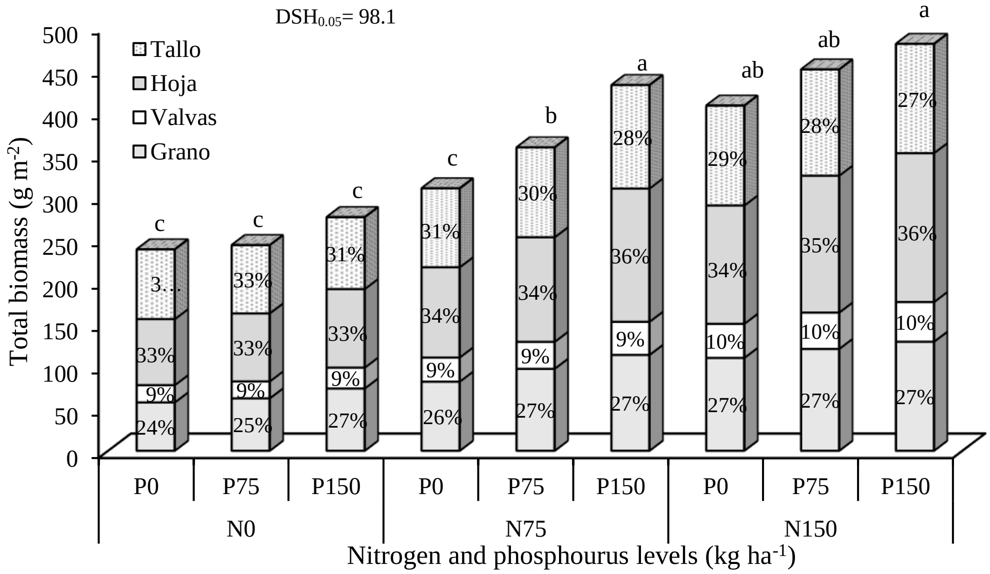

Figure 4. Total biomass and its distribution in the chickpea organs as a function of nitrogen and phosphorous levels. N0= 0, N75= 75 and N150= 150 kg of N ha^{-1}, P0= 0, P75= 75 and P150= 150 kg P ha^{-1}. $DMS_{0.05}$= minimum significant difference. Huitzuco, Guerrero. Summer 2017.

The application of N modified the distribution of BT in the plant, by reducing the accumulation of DM in the grain as the dose of N increased. With the application of N150, an increase of 3% of DM towards the grain was observed compared to the control treatment (N0). This response is attributed to the fact that N greatly favored the growth of the plant canopy and that, therefore, there is a greater source of photosynthates (Fageria and Baligar, 2005). The application of N75 and N150 decreased the biomass towards the stem by 7 and 6% in relation to the control (Figure 4).

Average growth rate of the crop

In general, the highest biomass accumulation per day occurred at 75 dds. N significantly stimulated the absolute growth rate (TCC), presenting the highest values with N150 (6.7 g m^{-2} day^{-1}), followed by N75 (5.2 g m^{-2} day^{-1}) and the lowest with the control (N0, 3.3 g m^{-2} day^{-1}). According to the regression model, the highest BT accumulation was achieved with N150 with a production of 0.32 g m^{-2}, while at N0 it generated the lowest TCC (0.17 g m^{-2}) (Figure 5).

On the other hand, P also significantly stimulated TCC, presenting the highest values with P150 (5.8 g m^{-2} day^{-1}), followed by P75 (5.2 g m^{-2} day^{-1}) and the lowest with the control (P0, 4.3 g m^{-2} day^{-1}). According to the regression model, the highest BT accumulation was achieved with P150 with a production of 0.29 g m^{-2}, while at P0 it generated the lowest TCC (0.24 g m^{-2}) (Figure 5). The increase in TCC with N is related to a larger canopy size measured through the number of green leaves, leaf area index and longer leaf area duration and, consequently, a higher IR.

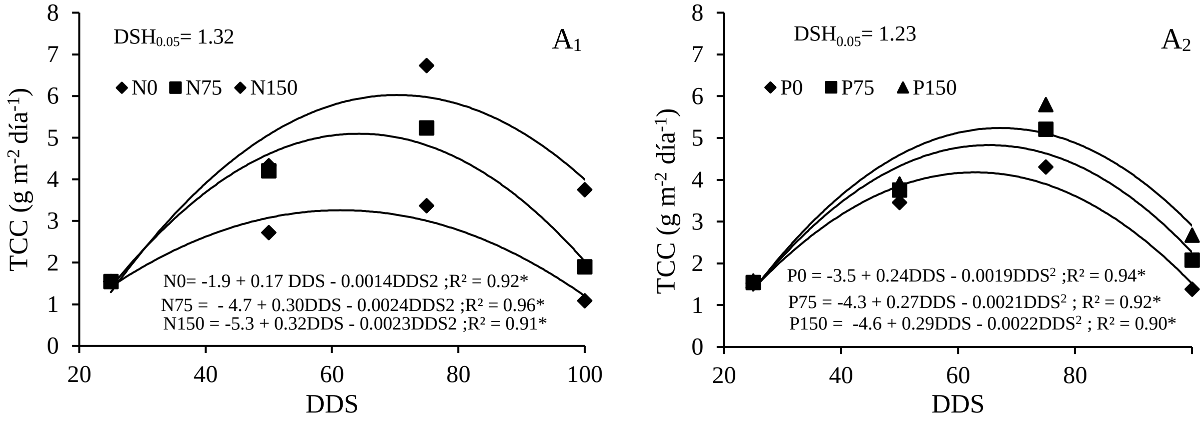

Figure 5. Dynamics of the average growth rate of the crop (TCC) in chickpea as a function of nitrogen (A1) and phosphorus (A2). $DSH_{0.05}$= minimum significant difference. Huitzuco, Guerrero. Summer 2017.

Similar trends are reported by Apáez *et al*., 2014 in chinese beans when presenting the highest values for TCC with the application of N150 and P150 (0.31 and 0.29 g m^{-2} day^{-1}, respectively). On the other hand, Escalante and Rodríguez (2014) in beans with application of N100 and P100, the TCC was higher than the control, from 30 to 80 days, similar to what was found in this study. This indicates that, in order to achieve greater biomass production, one must seek a larger canopy size and growth rate of the crop.

These results are attributed to the crop growth rate (TCC) which is considered an index of agricultural productivity, since it measures the weight gain of a plant community per unit area of soil (Castellanos, 2010). Furthermore, Escalante (1999) mentions that the increase in growth rates is related to greater biomass accumulation and higher grain yield.

On the other hand, the positive effect of N and P can be related in part to the low initial level of N-inorganic (0.11%) and P (14 ppm) in the soil. Therefore, by supplying fertilization with inorganic sources of N and P, the leaf area is increased and consequently the absorption of water and nutrients from the soil solution. This caused a larger canopy size, which according to Apáez *et al*. (2014) could allow to increase the interception of solar radiation, photosynthetic activity and consequently a higher RG.

Intercepted radiation

For the treatments studied, the intercepted radiation (IR) by the plant canopy during the crop cycle showed a positive relationship, which responded to a second degree polynomial (Figure 6). In this sense Apáez *et al*. (2014) in Chinese beans report that there is a positive response to BT and IR with the addition of the highest dose of N and P (N150 and P150). In relation to the above, there are data on other crops such as sunflower where a high relationship between BT and IR production has been found (Escalante, 1999). With the use of N, the efficiency in the use of radiation was higher, as can be seen in the coefficient of determination of the regressions presented.

Similar trends are reported by Morales *et al*. (2007) with the application of N and P. In the present study, P also caused increases in the efficiency in the use of radiation, but to a lesser degree than N (Figure 6). In summary, these results indicate that, with the application of N and P, the efficiency in the use of radiation increases, which is related to a greater and earlier ground cover by the plant canopy, attributable to a higher TCC.

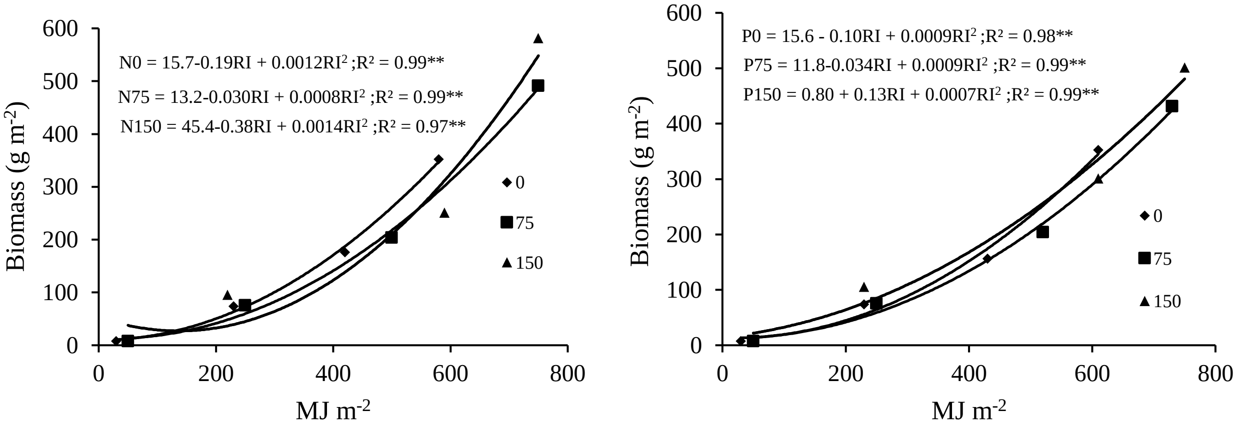

Figure 6. Total biomass as a function of intercepted radiation for nitrogen and phosphorus. N0= 0, N75= 75 and N150= 150 kg of N ha^{-1}, P0= 0, P75= 75 and P150= 150 kg P ha^{-1}. Huitzuco, Guerrero. Summer 2017.

Chickpea grain nutritional quality

N caused significant changes in the content of minerals, protein, fats, crude fiber (FC), soluble carbohydrates (CS), neutral detergent fiber (FDN), acid detergent fiber (FDA) and hemicellulose. While P in fats, CS, silica and hemicellulose. The N $*$ P interaction in minerals, proteins, fats, FC, CS, FDN, FDA, silica and hemicellulose (Table 1).

Table 1. Analysis of variance of the nutritional quality components for chickpea grain according to the N and P. Huitzuco, Guerrero. Summer, 2017.

Factor	Minerals	Proteins	Fats	Crude fiber	CS
N	**	**	**	**	**
P	ns	ns	**	ns	**
N∗P	**	**	**	*	**
Factor	FDN	FDA	Lignin	Silica	Hemicellulose
N	**	**	ns	ns	**
P	ns	ns	ns	*	**
N∗P	**	**	ns	*	**

*, ** = $p\leq$ 0.01 and 0.05, respectively; ns = not significant; N= nitrogen; P= phosphorus; CS= soluble carbohydrates; FDN= neutral detergent fiber and FDA= acid detergent fiber.

On average, 100 g of grain provide 3.5% of minerals, 1.6% of fats, 5.5% of raw fiber, 59.9% of soluble carbohydrates, 20.5% of FDN, 8.3% of FDA, 8.5% of lignin, 2.1 of silica and 29.2% protein (Tables 2 and 3). These values are higher than those reported by Danuta *et al*. (2015). Therefore, it is a food rich in proteins superior to common beans, which has ranges from 18 to 23% (Abubaker, 2008).

Table 2. Nutritional analysis (%) of dry weight of dry chickpea grain as a function of nitrogen (N) and phosphorus (P). Huitzuco, Guerrero. Summer 2017.

N	P	Minerals	Protein	Fats	Raw fiber	CS
0	0	3.1 bc	28 c	1.2 d	5.1 d	58.5 ef
	75	3.2 bc	28.2 c	1.2 d	5.1 d	57.8 bcd
	150	3.3 ab	28.5 c	1.4 cd	5.2 cd	57.9 f
75	0	3.3 bc	28.8 bc	1.4 cd	5.4 cd	59.1 def
	75	3.5 b	28.9 bc	1.4 cd	5.4 cd	59.5 cde
	150	3.7 ab	29.7 ab	1.5 c	5.4 cd	60.7 abc
150	0	3.8 ab	29.8 ab	1.8 b	5.6 bc	61.3 ab
	75	3.9 ab	30.2 a	1.8 b	6 a	61.8 a
	150	4.1 a	30.3 a	2 a	6 a	61.8 a
General mean		3.5	29.2	1.6	5.5	59.9
$DSH_{0.05}$		0.43	1.2	0.12	0.44	1.4
CV		3.83	1.73	3.3	3.35	0.99

Different letters in the same column indicate significant differences, according to Tukey (α= 0.05); $DSH_{0.05}$= honest significant difference at 5% probability. CV= coefficient of variation; CS= soluble carbohydrates.

Table 3. Nutritional analysis (% of dry weight) of the dry grain of chickpea as a function of nitrogen (N) and phosphorus (P). Huitzuco, Guerrero. Summer 2017.

N	P	FDN	FDA	Lignin	Silica	Hemicellulose
0	0	18.3 d	7.4 e	8.1 a	1.4 e	14.8 a
	75	19.7 c	7.4 e	8.8 a	1.7 bc	11.1 c
	150	19.8 c	7.6 e	8.4 a	1.4 e	11.7 bc
75	0	20.1 bc	8.1 d	8.7 a	1.4 e	12.2 bc
	75	20.5 bc	8.2 d	8 a	1.5 de	12.2 bc
	150	20.5 bc	8.3 cd	8.5 a	1.7 bc	12.6 bc
150	0	21.2 ab	8.5 c	8.5 a	1.7 bd	13 b
	75	21.5 ab	9 b	8.6 a	1.9 ab	13 b
	150	22.2a	9.4 a	8.6 a	2.1 a	14.8 a
General mean		20.5	8.3	8.5	1.6	12.2
$DSH_{0.05}$		1.43	0.32	0.9	0.23	1.44
CV		2.94	1.64	4.51	4.01	4.95

Different letters in the same column indicate significant differences, according to Tukey (α= 0.05); $DSH_{0.05}$= honest significant difference at 5% probability; CV= coefficient of variation; FDN= neutral detergent fiber and FDA= acid detergent fiber.

With the application of N150-P150, the highest values of minerals, proteins, fats, crude fiber, CS, FDN, FDA, silica and hemicellulose were presented in relation to N0-P0 (Tables 2 and 3). A similar response is reported by Alajaji and Adawy (2006), with a variation of 5.2% in protein content due to the effect of N. In other legumes such as common beans, the concentration of proteins increased. On the other hand, fertilization with N and P decreased the digestibility of the grain, by increasing the content of crude fiber, FDA and silica. Similar trends are reported in broad beans, as the crude fiber content increased by 0.48% (Galal *et al*., 2010).

With the application of N and P, the content of minerals, proteins, fats, FC, CS, FDN, FDA, silica and hemicellulose was improved (Tables 2 and 3). In this sense, fertilization with inorganic sources improves the nutritional quality of chickpea, mainly protein. With the combination N150-P150, N150-P75 the highest content of minerals, proteins, crude fiber, fats, CS, FDN, FDA, silica and hemicellulose was achieved (Tables 2 and 3). Thus, with these treatments, in addition to generating the highest RG, there is also a better nutritional quality.

Conclusions

The level of N and P did not modify the time to the occurrence of the phenological stages, but the grain yield, biomass accumulation, average growth rate of the crop, intercepted roots and nutrient content. The highest grain yield, biomass accumulation, average growth rate of the crop and intercepted roots are achieved with the N150-P150 combination. High doses of N and P increased the nutritional quality of the chickpea grain, by increasing the content of minerals, proteins, crude fiber, carbohydrates, FDN, FDA and lignin.

Cited literature

Abayomi, Y. A.; Ajibade, T. V.; Sammuel, O. F. and Sa'adudeen, B. F. 2008. Growth and yield responses of cowpea (*Vigna unguiculata* (L.) Walp) genotypes to nitrogen fertilizer (NPK) application in the Southern Guinea Savanna zone of Nigeria. Asian J. Plant Sci. 7(2):170-176.

Abubaker, S. 2008. Effect of plant density on flowering date, yield and quality attribute of bush bean (*Phaseolus vulgaris* L.) under center pivot irrigation system. Am. J. Agri. Biol. Sci. 3(4): 666-668.

Aguilar, G. L.; Escalante, E. J. A.; Fucikovsky, Z. L.; Tijerina, C. L. y Mark, E. E. 2005. Área foliar, tasa de asimilación neta, rendimiento y densidad de población en girasol. Terra Latinoam. 23(3):303-310.

Alajaji, S. A. and El-Adawy, T. A. 2006. Nutritional composition of chickpea (*Cicer arietinum* L.) as affected by microwave cooking and other traditional cooking methods. J. Food Composition Anal. 19(8):806-812.

Apáez, B. M.; Escalante, E. J. A. S.; Rodríguez, G. M. T. y Apáez, B. P. 2016. Distancia entre hileras, nitrógeno y producción de garbanzo en humedad residual. Rev. Mex. Cienc. Agríc. 7(2):223-234.

Apáez, B. P.; Escalante, E. J. A.; Rodríguez, G. M. T.; González, C. M. C. and Apáez, B. M. 2014. Analysis of growth and production in maize trellis with nitrogen and phosphorous. Int. J. Agriscience. 4(2):102-108.

Bejiga, G. and Van der Maesen, L. J. G. 2006. *Cicer arietinum* L. in Brink, M. and Belay, G. Plant resources of tropical Africa 1: Cereals and pulses. Wageningen/Blackhuys. Leiden/CTA, Netherlands: Prota Foundation. 42-46 pp.

Bernal, L. Coello, P.; Acosta, J. y Martínez, B. E 2007. Efecto de la deficiencia de fósforo en el metabolismo de carbono de plántulas de frijol (*Phaseolus vulgaris* L.). Agrociencia. 41(4):417-423.

Caliskan, S.; Ozkaya, I.; Caliskan, M. E. and Arslan, M. 2008. The effect of nitrogen and iron fertilization on growth, yield, and fertilizer use efficiency of soybean in Mediterranean type soil. Field Crops Res. 108(2):126-132.

Castellanos, M. S.; Abril, M. S. y López, C. E. Ñ. 2010. Análisis de crecimiento y relación fuente-demanda de cuatro variedades de papa (*Solanum tuberosum* L.) en el municipio de Zipaquirá (Cundinamarca, Colombia). Rev. Facultad Nacional de Agronomía-Medellín. 63(1):5253-5266.

Danuta, R. R.; Ewa, N. and Grażyna, B. 2015. Chickpeas-composition, nutritional value, health benefits, application to bread and snacks: a review. Critical Reviews in Food Science and Nutrition. 55(8):1137-1145.

Escalante, E. J. A. 1999. Área foliar, senescencia y rendimiento del girasol de humedad residual en función del nitrógeno. Terra Latinoam. 17(2):149-157.

Escalante, E. J. A. y Rodríguez G. M. T. 2011. Biomasa y rendimiento de haba en función de la densidad de población, nitrógeno y fósforo. Cienc. Agríc. Informa. 20(1):16-25.

Escalante, E. J. A.; Rodríguez, G. M. T y Escalante, E. Y. I. 2014. Tasa de crecimiento de biomasa y rendimiento de frijol en función del nitrógeno. Cienc. Tecnol. Agropec. 2(1):1-8.

Fageria, N. K. and Baligar, V. C. 2005. Enhancing nitrogen use efficiency in crop plants. Elsevier Inc. 88(1):97-185.

FAOSTAT. 2019. Producción mundial de garbanzo. En línea http: www.faostat.fao.org.

Galal, O. A.; Izzeldin, F. A. and ElHassan, G. A. 2010. Effects of biological and mineral fertilization on yield, chemical composition and physical characteristics of faba bean (*Vicia faba* L.) cultivar Seleim. Pakistan J. Nutr. 9(7):703-708.

García, M.; Herrera, P.; Birbe, B.; Colmenares, O. y Martínez, N. 2002. Efecto de dos densidades de siembra y cinco edades de cosecha sobre el rendimiento y calidad del heno de follaje de frijol bayo (*Vigna unguiculata* (L.) Walp). Rev. Cient. 12(2):584-586.

Goñi, I. and Gamazo, C. V. 2003. Chickpea flour ingredients lows glycemic response to past in healthy volunteers. Food Chemistry. 81(4):511-515.

Grelda, A; Farlas Y; Moreno V. J. G; Ma. del R. Falcon V. and Barron H J M. 1997. Isolation and partial characterization of starches from dry beans (*Phaseolus vulgaris* L.) and chickpeas (*Cicer arietinum* L.) grown in Sonora, Mexico. Starch. 49(9):341-345.

Hunt, R. 1990. Basic growth analysis. Unwinn Hyman. London, UK. 112 p.

Kaur, M. and Singh N. S. 2005. Physicochemical, cooking, textural and roasting characteristics of chickpea (*Cicer arietinum* L.) cultivars. J. Food Eng. 69(4):511-517.

Kozera, W.; Barczak, B.; Knapowski, T. and Ralcewicz, M. 2013. Total and fractional contents of proteins in bean seeds under the conditions of varied fertilization with microelements. J. Cent. Eur. Agr. 14(1):319-327.

Morales, R. E. J., Escalante, E. J. A. y López S, J. A. 2007. Producción de biomasa y rendimiento de semilla en la asociación girasol (*Helianthius annuus* L.)-frijol *(Phaseolus vulgaris* L.) en función del nitrógeno y fósforo. Ciencia Ergo Sum. 14(2):177-183.

Muhammad, I. C.; Adu-Gyamfi, J. J.; Saneoka, H.; Tran, N. N.; Suwa, R.; Kanai, S.; Hany, A.; Shemy, E.; Lightfoot, D. and Fujita, K. 2008. The effect of phosphorus deficiency on nutrient uptake, nitrogen fixation and photosynthetic rate in mashbean, mungbean and soybean. Acta Physiol Plant. 30(4):537-544.

Olaleye, O.; Olajire, F.; Aboido, R. C. and Nnenna, I. 2011. Nitrogen and phosphorus response efficiency in cowpea genotipes. J. Agric. Sci. 4(1):81-90.

SAS. 2003. Statistical Analysis System Institute. SAS user's guide. Statistics. Version 8. SAS Inst., Cary, NC. USA. Quality, and elemental removal. J. Environ. Qual. 19:749-756.

SIAP. 2019. Avance de siembras y cosechas. http://www.siap.gob.mx.

Sosa, P. E. 1979. Manual de procedimientos analíticos para alimentos de consumo animal. Departamento de Zootecnia. Universidad Autónoma Chapingo (UACH). Texcoco, Estado de México. 115 p.