



**ARTICLE**

## Analysis of Growth and Productivity of Green Chickpea Using Nitrogen and Phosphorus Fertilization

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### ABSTRACT

Chickpea contains high levels of protein, vitamins and minerals. Acceptable chickpea yield is the result of meeting nitrogen and phosphorus requirements. The effect of appropriately meeting such requirements reflects on growth and can easily be evaluated using growth analysis. This research determined: (a) The effect of nitrogen and phosphorus fertilization on phenology, net assimilation rate, number of green leaves, leaf area, leaf area index and leaf area duration; (b) Green chickpea yield and number of pods due to fertilization; and (c) The combination of nitrogen and phosphorus fertilization that yields the most net revenue. Nitrogen and phosphorus fertilization was evaluated; each at the doses of 0, 75 and 150 kg ha<sup>-1</sup> (N0, N75, N150; P0, P75 and P150, respectively). The combination of the levels of both nutrients generated nine combinations of treatments which were distributed in the field in a randomized complete block design in an arrangement of divided plots with four repetitions. Timing of phenological phases were similar among treatments. Nitrogen and phosphorus fertilization increased number of leaves, leaf area index, and leaf area duration that translated into increased green chickpea yield (GCY). Combinations N150-P75 and N150-P150 produced the highest GCY. The highest net revenue and revenue per peso invested was obtained with N150-P75.

### KEYWORDS

*Cicer arietinum*; economic analysis; leaf area; number of leaves; yield

## 1 Introduction

Chickpea (*Cicer arietinum*) is a legume from India, mostly sown in Turkey, Pakistan and Mexico. World production for 2015 was 8.3 million tons for human consumption [1]. In Mexico, chickpea is commercially sown in Sinaloa, Sonora, Michoacán, Guanajuato, Baja California Sur, Jalisco and Guerrero [2]. Chickpea is an excellent source of tryptophan and phenylalanine. These essential amino acids increase the sensation of satiety and might contribute to obesity reduction [3]. Chickpea can provide between 11% to 14% of fiber, from 8% to 24% of iron and from 17% to 24% of magnesium to the recommended daily intake. In average, the seed contains 7.8 g protein per 100 g of fresh seed (IDR, NOM/051/SCFI/SSA1-2010), and it has more calcium, iron and potassium than faba bean (*Vicia faba* L.), ayocote (*Phaseolus coccineus* L.)



and green bean (*Pisum sativum* L.) [4]. Chickpea is harvested green, which results in less than 50% of the required nitrogen by the crop from biological fixation [5].

Fageria et al. [6] mentioned that nitrogen is the nutrient that determines yield. It is an integral part of chlorophyll and essential amino acids for protein synthesis. Likewise, phosphorus takes part in several physiological processes like germination, seedling development, root growth, and start of fructification. It is a necessary component of the plant-rhizome symbiosis, and it affects biological nitrogen fixation [7]. Nitrogen and phosphorus influence yield under rainfed conditions by increasing size and duration of the canopy, and thus modify the photosynthetic machinery [8,9]. Reports have pointed out that size and duration of the photosynthetic apparatus are tightly related to number of pods and yield [10]. The physiological causes of grain yield following fertilization can be determined with a growth analysis. This analysis quantifies important characteristics like growth rate, length of the vegetative cycle, biomass production efficiency, and biomass production rate in every phenological stage, as well as biomass distribution in every organ of the plant. Additionally, it is possible to calculate net assimilation rate (NAR) to determine photosynthate production and photosynthetic activity. Ultimately, the size of the photosynthetic source depends on number of leaves and leaf area [11]. Chickpea is a good alternative for small-scale producers. It is sold as green grain (green chickpea) and reaches up to 50% higher economic revenue than dry grain [12]. Greater yield might be promoted by nitrogen and phosphorus fertilization to promote canopy growth [13]. Chemical fertilizers, particularly those with nitrogen and phosphorus, have increased their price as a consequence of high demand and high production costs [14]. Economic viability of chemical fertilization on chickpea must then be evaluated. The optimal dose that produces the highest net revenue, regardless of yield, can be determined by evaluation of the response to different levels of phosphorus and nitrogen fertilization.

Apáez et al. [15] found a high nitrogen dose ( $100 \text{ kg ha}^{-1}$ ) increases crop profitability and results chickpea in the highest yield per surface area. However, few studies have focused on chickpea. Therefore this study determined: (a) The effect of nitrogen and phosphorus fertilization on phenology, net assimilation rate, number of green leaves, leaf area, leaf area index and leaf area duration; (b) Yield components and green chickpea yield after nitrogen and phosphorus fertilization; and (c) The optimal combination of nitrogen and phosphorus fertilization that produces the highest net revenue.

## 2 Materials and Methods

The study was located in Huitzuco, Guerrero, Mexico at  $18^{\circ} 15' \text{ N}$ ,  $99^{\circ} 09' \text{ W}$  and 1086 m above sea level. The climate in the region is  $\text{AW}_1$  corresponding to warm subhumid with rain in summer [16]. The chickpea seed employed in this research was a white grain, regional landrace. Seeds were sowed under rainfed conditions on June 1, 2017. The population density was  $15 \text{ plants m}^{-2}$ . Nitrogen and phosphorus was applied in treatments that combined 0, 75 and  $150 \text{ kg ha}^{-1}$  of each nutrient ( $\text{N}_0$ ,  $\text{N}_{75}$  and  $\text{N}_{150}$ ;  $\text{P}_0$ ,  $\text{P}_{75}$  and  $\text{P}_{150}$ , respectively). These combinations of nitrogen and phosphorus fertilization created nine treatments. All the phosphorus dose and half of the nitrogen treatment were applied 20 days after sowing (das) and the rest at 45 das. Urea (46% nitrogen) and triple calcium superphosphate (46%  $\text{P}_2\text{O}_5$ ) supplied the nutrients. Trials were set up in random blocks, in a split-plot arrangement with four repetitions. The N corresponded to the large plot and the P to the small plot. Physical and chemical analyses were performed on the soil to determine basal fertility levels. The characteristics of the soil were: 39% clay, 25% sand, 36% silt corresponding to loamy clay, high organic matter content (3.51%), a  $1.25 \text{ g cm}^{-3}$  apparent density, pH 7.2 (slightly alkaline), low electric conductivity ( $0.32 \text{ dS m}^{-1}$ ), low inorganic nitrogen content ( $3.0 \text{ mg kg}^{-1}$ ), and medium phosphorus content ( $11 \text{ mg kg}^{-1}$ ).

During the whole crop cycle, maximum and minimum temperature ( $T_{\text{max}}$ ,  $T_{\text{min}}$ , respectively;  $^{\circ}\text{C}$ ) were recorded; accumulated rainfall (mm) was registered. The data were collected from the 12115 Huitzuco (DGE)-GRO weather station ( $18^{\circ} 30' \text{ N}$  and  $99^{\circ} 32' \text{ W}$ ). Phenological stages were recorded on criteria

proposed by Padilla et al. [17]: Days to emergence (E), days to flowering (R1), days to fructification (R2) and days to end of fructification (R3). Green chickpea yield (GCY,  $\text{g m}^{-2}$ ) was determined by harvesting at 100 das. Number of green leaves (NGL, leaves  $\text{m}^{-2}$ ) and leaf area (the leaf area was measured with a LICOR 3100 leaf area integrator,  $\text{cm}^2$ ) were recorded in each of five plants sampled from the central row of the useful plot in each experimental unit at 25, 50, 75 and 100 das. Leaf area index (LAI) was calculated at 25, 50, 75 and 100 das. See Eq. (1). Leaf area duration (LAD) was recorded from emergence to 100 das. See Eq. (2):

$$LAI = \frac{LA}{NP} \times \frac{PD}{100 \text{ dm}^2} \quad (1)$$

where LA = leaf area ( $\text{dm}^2$ ); NP = number of sampled plant; and PD = number of plants  $\text{m}^{-2}$ .

$$LAD = \sum (LAI_1 + LAI_2) \times \frac{(T_2 - T_1)}{2} \quad (2)$$

where  $\sum$  = sum of the leaf area duration in each sample point;  $LAI_1$  = leaf area index at a starting point ( $T_1$ , days);  $LAI_2$  = leaf area index at a final point ( $T_2$ , days) [11].

Total biomass (TB,  $\text{g dry matter m}^{-2}$ ) was registered for each organ in the plant (stems, leaves, pods and grain). Samples were dried in a forced-air oven at  $80^\circ\text{C}$  until constant weight was registered. Average net assimilation rate (NAR) was calculated for the same periods (sowing to 25 das, 25 to 50 das, 50 to 75 das and 75 to 100 das with the collected biomass data). The equations for NAR were. See Eq. (3):

$$NAR = \frac{\frac{DW_2 - DW_1}{LA_2 - LA_1}}{\frac{\ln LA_2 - \ln LA_1}{T_2 - T_1}} \quad (3)$$

where  $DW_1$  and  $DW_2$  are dry biomass weight;  $\ln LA_2$  and  $\ln LA_1$  are the natural logarithm on leaf area at time  $T_2$  and  $T_1$ , respectively.

Data was analyzed with SAS version 9.0. Differences among treatments were calculated by Tukey mean comparison at 5% probability [18]. An economic analysis was performed with the data [19].

### 3 Results and Discussion

#### 3.1 Climate and Phenology

During the crop cycle, the average minimum ( $T_{\min}$ ) and maximum ( $T_{\max}$ ) temperature was  $17^\circ\text{C}$  and  $34^\circ\text{C}$ , respectively. The highest temperatures were registered from sowing to 50 das ( $T_{\max} = 35^\circ\text{C}$ ;  $T_{\min} = 17^\circ\text{C}$ ). After this period, temperature decreased until the end of fructification (R3); the lowest temperature was registered at 100 das ( $16^\circ\text{C}$ ), exactly when green chickpea was harvested. Accumulated rainfall was 633 mm: 64% (409 mm) occurred from sowing to start of flowering (R1), and 36% (224 mm) accumulated in the reproductive stage from R1 to R3 (end of fructification). Climate conditions, temperature and rainfall, during this study were appropriate for chickpea crops; the recommended temperature range is 10 to  $25^\circ\text{C}$ , and the optimal temperature is  $20^\circ\text{C}$  [20]. Timing of the phenology stages occurred similarly among treatments. Emergence (E) started at 10 das, start of flowering (R1) started at 55 das, and end of fructification was recorded at 100 das (Tab. 1). Similar behavior is mentioned by Apez et al. [15]: Timing of phenological stages was not modified by nitrogen fertilization. However, Abayomi et al. [21] reported contrasting results that indicated nitrogen and phosphorus fertilization reduced crop cycle by 6 days.

**Table 1:** Average decennial maximum and minimum temperature and decennial sum of rainfall during the chickpea crop cycle. Huitzuco, Guerrero. Summer 2017

Month	Decennial	Tmax °C	Tmin °C	Rainfall	Phenological stages
June	1	35.8	17.8	82.0	S-E
June	2	35.3	17.7	91.0	
June	3	34.7	17.1	115.0	
July	4	34.9	17.0	45.1	
July	5	34.7	16.3	23.7	
July	6	33.3	16.3	53.1	R1
August	7	33.7	16.4	48.5	
August	8	33.1	16.1	56.3	R2
August	9	32.3	16.3	82.0	
October	10	32.1	16.0	36.0	R3

Note: S = Sowing, E = Emergence, R1 = Start of flowering, R2 = Start of fructification, R3 = End of fructification.

### 3.2 Number of Green Leaves, Leaf Area Index and Leaf Area Duration

The number of green leaves (NGL), leaf area index (LAI) and leaf area duration (LAD) showed significant differences due to fertilization with either nitrogen or phosphorus and their interaction N\*P presents significant differences at 75 and 100 das. For the LAI variable the factor N generates highly significant differences at 50, 75 and 100 das, P and the interaction generate differences at 75 and 100 das. On the other hand, the LAD variable, the N factor and the interaction present highly significant differences, while P presents significant differences (Tabs. 2 and 3). Treatment N150 produced increments of 82%, 92% and 62% to NGL, LAI and LAD, respectively; the N75 treatment followed by increasing the same variables by 46%, 46% and 35%, respectively, in relation to the control treatment. These results are in line with Escalante et al. [9]: NGL can be modified as the emergence rate for leaves changes with nutrition, and nitrogen fertilization delays leaf senescence. In this research, greater number of leaves per plant were counted at 100 das due to fertilization. Caliskan et al. [22] mentioned that nitrogen fertilization increases production rates of photosynthates and chlorophyll pigments. This effect reflects on LAI. Similar tendencies were reported by Abayomi et al. [21] in cowpea [*Vigna unguiculata* (L.) Walp]. They found that nitrogen fertilization delayed leaf senescence and increased the number of leaves, NGL, LAI and LAD.

**Table 2:** Significance of number of green leaves (NGL), leaf area index (LAI), leaf area duration (LAD) and net assimilation rate (NAR) of chickpea as a response of nitrogen (N), phosphorous (P) fertilization and interaction of N\*P. Huitzuco, Guerrero. Summer 2017

Factor		NGL (leaves m <sup>-2</sup> )				LAI				LAD
		25	50	75	100	25	50	75	100	100
Days after sowing										
Prob. F	N	NS	*	*	*	NS	*	**	**	**
	P	NS	NS	*	*	NS	NS	**	*	*
	N*P	NS	NS	*	*	NS	NS	**	**	**

Note: \*, \*\* =  $P \leq 0.01$  and  $0.05$ , respectively, NS = not significant.

**Table 3:** Number of green leaves (NGL), leaf area index (LAI), and leaf area duration (LAD) of chickpea as a response of nitrogen (N) and phosphorous (P) fertilization. Huitzuco, Guerrero. Summer 2017

N	P	NGL (leaves m <sup>-2</sup> )				LAI				LAD
		25	50	75	100	25	50	75	100	100
kg ha <sup>-1</sup>		Days after sowing								
Nitrogen (N)	0	16a <sup>¶</sup>	77b	117c	123c	0.2a	0.4b	0.96c	1.08c	53c
	75	16a	95a	153b	179b	0.2a	0.6a	1.34b	1.58b	72b
	150	16a	100a	181a	225a	0.2a	0.6a	1.64a	2.08a	86a
Phosphorus (P)	0	15a	88a	137b	160b	0.2a	0.5a	1.19b	1.38b	65b
	75	16a	90a	147b	170b	0.2a	0.5a	1.30b	1.48b	69b
	150	17a	93a	167a	198a	0.2a	0.5a	1.45a	1.78a	77a
General average		16	90	150	176	0.2	0.6	1.31	1.54	70.3
(SD <sub>0.05</sub> )	N	(2)	(12)	(23)	(28)	(0.04)	(0.05)	(0.2)	(0.4)	(10)
	P	(3)	(9)	(12)	(12)	(0.04)	(0.09)	(0.2)	(0.2)	(5)
CV		7.2	89.6	10.2	12.1	10.2	13.7	14.1	10.1	6.3

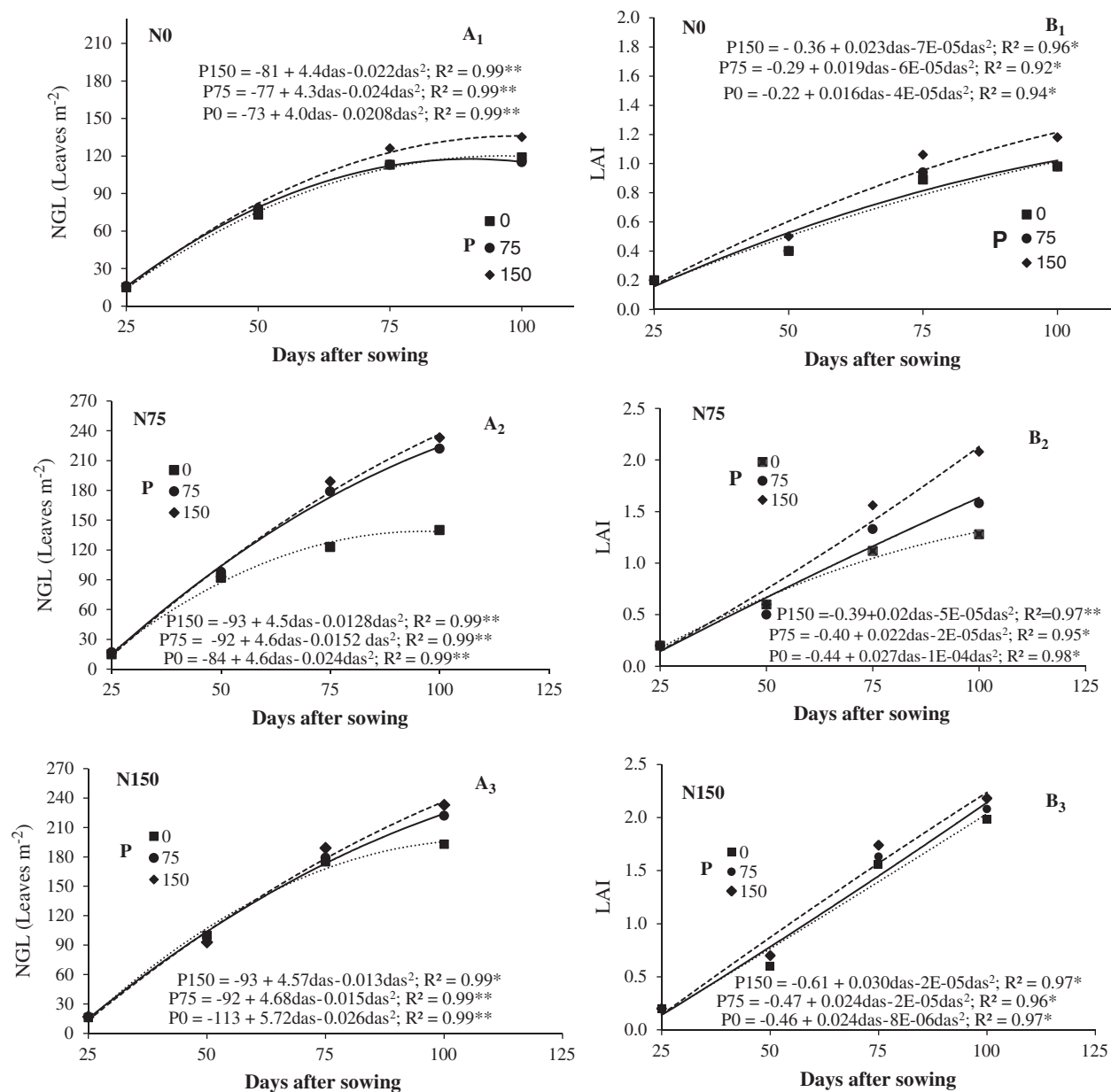
Note: <sup>¶</sup>Different letters in the same column indicate significant differences (Tukey  $\alpha = 0.05$ ). SD<sub>0.05</sub> = minimum significant difference at 5% error probability. CV = coefficient of variation; NGL = number of green leaves; LAI = leaf area index; LAD = leaf area duration.

At the end of the cycle (100 das), P150 produced the highest NGL, LAI and LAD. These variables increased by 23%, 28% and 18%, respectively. P75 caused minimal changes on the photosynthetic apparatus: 8% increase in size (NGL and LAI) and 6% longer duration (LAD). This response is similar to the results reported by Olivera et al. [23]. The authors described a positive effect of phosphorus on leaf size, and thus on LAI. Muhammad et al. [24] reported that supplying phosphorus promotes greater leaf area on soybean [*Glycine max* (L.) Merrill], cowpea and mungo bean [*Vigna radiata* (L.) Wilczek]. Their results showed 64%, 95% and 90% increments, respectively, when compared to a non-fertilized control.

The results in these research might be explained by reduced photosynthetic rates caused by phosphorus deficiency. This deficiency directly affects leaf area development and photosynthetic capacity per unit of leaf area. Nitrogen fixation is also reduced as a consequence of diminished nitrogenase activity, smaller root growth, fewer leaves, fewer knots, fewer branches, slower relative rate of leaf emergence and slower leaf expansion [24].

Fig. 1 shows the rates of NGL emergence and LAI. The curves were fitted to a second degree polynomial. NGL and LAI increase as the crop cycle advances and then decrease because of senescence. When nitrogen was supplied, increments were more pronounced as the greater NGL indicates. Treatments N75-P150 and N150-P150 increased NGL by 86% to 95%, respectively, while LAI increased 22% to 12%, respectively, when measured at 100 das. The highest values for NGL and LAI occurred at 100 das. Nitrogen fertilization significantly increased NGL and LAI from 50 das, while the effect of phosphorus fertilization was observed from 75 das. Up to that moment, the basal nitrogen and phosphorus levels in the soil might have been enough to satisfy the nutritional requirements of the crop. Similar tendencies were found by Apáez et al. [13]. They reported that biomass and yield of cowpea bean increased in response to additional nitrogen and phosphorous fertilization.

Regarding the N\*P interaction, it was found that the response of chickpea to fertilization with P on NGL and LAI, was greater with the application of N75, as the highest increases in these variables occurred at 75 and 100 days with the supply of P75 and P150, in comparison with the control without application (P0) as observed in Fig. 1. Likewise, the application of N75 favored more the response of the chickpea to the application of P over the duration of the foliar area.

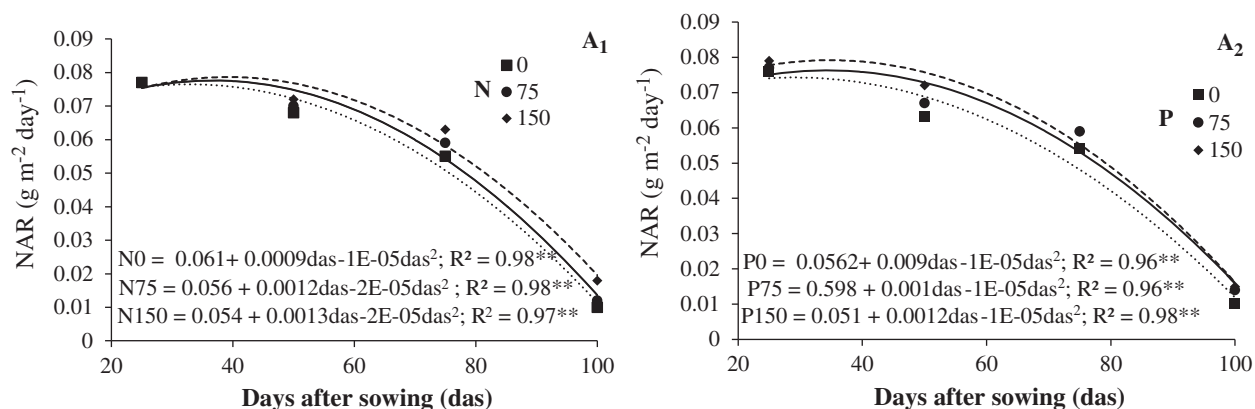


**Figure 1:** Number of green leaves (NGL, A<sub>1</sub>, A<sub>2</sub> y A<sub>3</sub>) and leaf area index (LAI, B<sub>1</sub>, B<sub>2</sub> y B<sub>3</sub>) of chickpea in response to nitrogen (N) and phosphorous (P) fertilization. Huitzuco, Guerrero. Summer 2017. das = days after sowing

### 3.3 Average Net Assimilation Rate

All treatments showed the highest net assimilation rate (NAR) from 25 to 40 das, and as the crop cycle advanced, it decreased to the lowest recorded values at 100 das. This behavior might be caused by shading of the inferior canopy layers from the uppermost canopy. Additionally, in the last stage of the crop cycle, leaf senescence rate increases [8]. Chickpea with added nitrogen had the highest NAR from 40 das. N150 treatment increased NAR by  $0.008 \text{ g dm}^{-2} \text{ day}^{-1}$ , while N75 increased NAR by  $0.002 \text{ g dm}^{-2} \text{ day}^{-1}$  when compared to the control (N0). These results suggest nitrogen stimulates photosynthetic efficiency of

the canopy (Fig. 2). Reported nitrogen fertilization increased photosynthetic activity by increasing Rubisco activity and chlorophyll concentration in the leaves. A similar response was found with N75 and N150 treatments by Apáez et al. [8] in cowpea who applied 100 kg of nitrogen ha<sup>-1</sup>. Phosphorus fertilization modified NAR and had maximum values of 0.015 g dm<sup>-2</sup> day<sup>-1</sup> for P150 (Fig. 2). In 2014, Apáez et al. [25] found high NAR values when N150 and P150 were applied to cowpea (0.0016 g dm<sup>-2</sup> day<sup>-1</sup> y 0.0014 g dm<sup>-2</sup> day<sup>-1</sup>, respectively).



**Figure 2:** Net assimilation rate (NAR) curves of chickpea in response to nitrogen (A<sub>1</sub>) and phosphorous (A<sub>2</sub>). Huitzuco, Guerrero. Summer 2017

### 3.4 Green Chickpea Yield and Yield Components

Green chickpea yield (GCY) and number of pods (NP) showed significant changes for nitrogen (N) and phosphorus (P) fertilization (Tabs. 4 and 5). For the GCY variable, N and N\*P generate highly significant differences, while P causes significant differences. For N\*P the factor N and P generate significant differences, while the interaction N\*P does not generate differences. The results indicate that the application of N and P, as well as the N\*P interaction generate significant differences at the end of the crop cycle since they modify the values of the evaluated variables (Tab. 4).

**Table 4:** Significance of green chickpea yield (GCY) and number of pods (NP) of chickpea as a response of nitrogen (N), phosphorous (P) fertilization and interaction of N\*P. Huitzuco, Guerrero. Summer 2017

Factor		GCY g m <sup>-2</sup>	NP pods/m <sup>-2</sup>
Prob. F	N	**	**
	P	*	*
	N*P	**	NS

Note: \*, \*\* =  $P \leq 0.01$  and  $0.05$ , respectively, NS = not significant.

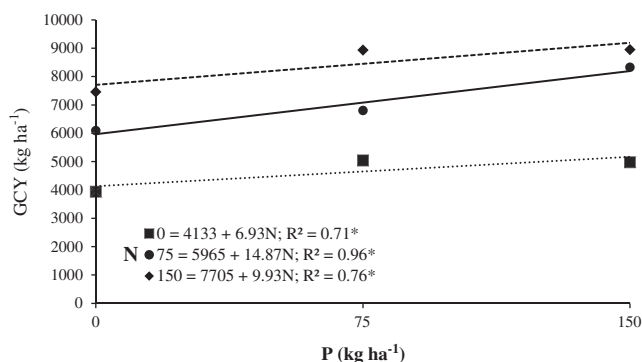
GCY and NP increased with added nitrogen, phosphorus (Tab. 5). P150 had the highest GCY and NP. Comparisons to the control treatment (N0) showed increments of 83% for GCY and 60% for NP. N75 was the second best treatment; it caused increments of 46% and 30% on GCY and NP, respectively. Phosphorus fertilization favored chickpea production too; however, its effect was less visible than nitrogen fertilization. The basal phosphorus level in the soil might have been sufficient to cover initial crop requirements. Tab. 5 shows that the highest increment was achieved from N75; GCY and NP increased 27% and 17%, respectively.

**Table 5:** Green chickpea yield and yield components in response to nitrogen (N) and phosphorous (P) fertilization. Huitzuco, Guerrero. Summer 2017

Nutrient kg ha <sup>-1</sup>	Level	GCY g m <sup>-2</sup>	NP Pods/m <sup>-2</sup>
N	0	466c <sup>¶</sup>	93c
	75	737b	121b
	150	846a	136a
P	0	584b	106b
	75	693a	119a
	150	743a	124a
General average		673	116
(SD <sub>0.05</sub> )	N	84	9
	P	76	8
CV		8.9	11.6

Note: <sup>¶</sup>Different letters in the same column indicate significant differences (Tukey  $\alpha = 0.05$ ). SD<sub>0.05</sub> = minimum significant difference at 5% error probability. CV = coefficient of variation; GCY = Green chickpea yield; NP = number of pods.

Thus, N150-P75 and N150-P150 statistically increased GCY and NP; both treatments improved GCY by 501 g m<sup>-2</sup> and NP by 56 pods m<sup>-2</sup> compared to the unfertilized control. The middle fertilization level (N75-P75) increased GCY by 500 g m<sup>-2</sup> and NP by 56 pods m<sup>-2</sup>. The increase in GCY at P150 was 9.93 kg per kilogram of nitrogen used, while on the control treatment (P0) the increment was only 6.93 kg per kilogram of nitrogen used. P75 was the dose that most favored the nitrogen response on GCY with increases of 14.87 kg per kilogram of nitrogen applied (Fig. 3). NP increased to 0.72 pods m<sup>-2</sup> when P150 was applied, but it only increased 0.37 pods m<sup>-2</sup> with the control (P0).

**Figure 3:** Green chickpea yield (GCY) in response to nitrogen and phosphorous. Huitzuco, Guerrero. Summer 2017

Regarding the N\*P interaction, the response of the chickpea to the application of P on GCY was greater with the application of N75, as the greatest increases were obtained in these variables (Tab. 4 and Fig. 3).

Namvar et al. [26] mentioned fertilization of 100 kg of nitrogen ha<sup>-1</sup> caused GCY and NP to increase by 52% and 22%, respectively, compared to the control treatment (N0). This behavior results from increased cellular division and enzymatic activity by nitrogen fertilization and results in higher dry matter



accumulation in the grain. The positive response to added nitrogen as measured on yield promotes an increment on numbers of branches, flowers, and pods [21]. Several studies show nitrogen and phosphorus fertilization favor the production of pods and grains [27]. Significant effects on grain yield were reported by Walley et al. [28], too, when nitrogen and phosphorus were added ( $45 \text{ kg ha}^{-1}$ ). Compared to the control treatment, grain yield was 14% higher when nitrogen was supplied and 7% when phosphorus was added. Addition of these nutrients has positive effects. The differences reported in this research could be attributed to several factors, mainly genotype (Type Desi cv myles) and weather conditions. The effect observed for added phosphorus was also found by Fageria et al. [29]. They found that additional phosphorus stimulates growth, root activity and nodule formation. Deficiency of phosphorus, as reported by Lynch et al. [30], reduces photosynthesis since it has a central role in energy transport, storage and transfer. Additionally, an adequate phosphorus supply increases grain size, number and viability [24]. Lastly, the results in this research indicate higher green grain yield and pod number in chickpea are achieved when nitrogen is applied; the supplemental nitrogen promotes increases photosynthetic apparatus size (NGL and LAI) and its duration (LAD).

### 3.5 Economic Analysis

The economic analysis for green chickpea yield (GCY) is shown in Tab. 6. The highest GCY and total revenue (TR) was achieved by fertilization with the N150-P150 treatment. However, this level of fertilization had the highest variable (VC) and total (TC) costs, and net revenue (NR) was \$1,310.55 lower than the NR for the N150-P75 treatment. Revenue per invested peso (RIP) varied from \$2.64 to \$5.58, and the highest RIP was obtained with the N150-P75 treatment. Other researchers report the highest yield occurs when the highest nitrogen dose is used ( $100 \text{ kg ha}^{-1}$ ) for chickpea [15]. Treatments without added nitrogen had the lowest RIP; increments on phosphorus dose reduce RIP. The yield increments in chickpea caused by phosphorus-only fertilization are not enough to amortize the cost of fertilizers.

**Table 6:** Green chickpea yield (GCY), total income (TR), fixed costs (FC), variable costs (VC), total costs (TC), net income (NR), and revenue per invested peso (RIP) in response to nitrogen (N) and phosphorous (P) fertilization. Huitzuco, Gro. Summer 2017

N	P	GCY	TR	FC	VC	TC	NR	RIP
	kg ha <sup>-1</sup>					\$MXN		
0	0	3,940e	98,500.00e	12,900.00a	14,126.80c	27,026.80c	71,473.20e	2.64c
	75	5,040de	126,000.00dc	12,900.00a	16,115.36b	29,015.36b	96,984.64dc	3.34c
	150	4,980de	124,500.00de	12,900.00a	17,761.01b	30,661.01b	93,838.99dc	3.06c
75	0	6,100cd	152,500.00cd	12,900.00a	16,725.33b	29,625.33b	122,874.67cd	4.15b
	75	6,810bc	170,250.00bc	12,900.00a	19,072.09a	31,972.09b	138,277.91bc	4.32b
	150	8,330ab	208,250.00ab	12,900.00a	20,978.84a	33,878.84a	174,371.16ab	5.15a
150	0	7,460abc	186,500.00abc	12,900.00a	19,334.06a	32,234.06a	154,265.94abc	4.79b
	75	8,940a	223,500.00a	12,900.00a	21,090.72a	33,990.72a	189,509.28a	5.58a
	150	8,950a	223,750.00a	12,900.00a	22,651.27a	35,551.27a	188,198.73a	5.29a

Note: Total revenue = yield \* Price per kilogram of Green chickpea (\$ 25.00). Fixed cost = costs of field labor, pest and disease control. Variable costs = costs of fertilizers, harvest and shipping. Total costs = fixed costs + variable costs. Net revenue + total revenue-total costs.

## 4 Conclusion

Fertilization with nitrogen and phosphorus has no effect on timing of phenology stages among treatments. However, it improved net assimilation rate and increased of number of green leaves, leaf area

index, leaf area duration, green chickpea yield and number of pods. Nitrogen has bigger effects than phosphorus on those variables. The nitrogen and phosphorus combinations that improve growth and increase green chickpea production are N150-P75 and N150-P150. The highest net revenue and revenue per invested peso is achieved with N150-P75.

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