Biological Forum – An International Journal **15(10): 436-446(2023)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Differential Response of Chickpea (*Cicer arietinum* L.) Genotypes under Organic and Inorganic Input Conditions

Jeevanjot Kaur[1]*, Neelam Bhardwaj[2] and Sunidhi Tiwari[1]
[1]Student, *Department of Plant Breeding and Genetics, CSK HPKV, Palampur (Himachal Pradesh), India.*
[2]Scientist, *Department of Plant Breeding and Genetics, CSK HPKV, Palampur (Himachal Pradesh), India.*

(Corresponding author: Jeevanjot Kaur)*
(Received: 27 July 2023; Revised: 26 August 2023; Accepted: 23 September 2023; Published: 15 October 2023)
(Published by Research Trend)

ABSTRACT: The present investigation entitled "Genetic analysis for seed yield and related traits in chickpea (*Cicer arietinum* L.) under organic and chemical input conditions" was undertaken during *rabi* 2018 to assess the nature and magnitude of genetic variability and associations among various traits. Analysis of variance revealed significant genetic differences among chickpea genotypes for all the traits under organic and chemical input conditions except pod width and pod length under organic input conditions and nitrogen fixation under both the conditions. In general, mean and range for most of the traits were found to be higher under organic input conditions as compared to chemical input conditions. High PCV, GCV, heritability and genetic advance were observed for nodule number, nodule fresh weight, nodule dry weight and seed yield per plant under both the conditions. Under organic input conditions seed yield per plant was significantly positively correlated with secondary branches, pods per plant, nodule number, nodule fresh weight, nodule dry weight, harvest index and biological yield per plant whereas under chemical input conditions seed yield per plant was significantly positively correlated with primary branches per plant, secondary branches per plant, pods per plant, 100-seed weight, harvest index and biological yield per plant implying that these traits can act as selection indices for seed yield. On the basis of mean performance, best genotypes for seed yield common under both the conditions are 18-II, 113-P, P-30-6 and DKG-964.

Keywords: Organic input conditions, chemical input conditions, differential response, selection index.

INTRODUCTION

Legumes are significant sources of carbohydrates and largest producer and consumer of legumes in world is India. Chickpea (*Cicer arietinum* L.) is an important leguminous cool-season crop belonging to the family leguminaceae (Mallikarjuna *et al.*, 2017). It is the world's third most important food legume (pulse) after dry common bean and field pea (Padmavathi *et al.*, 2013). The grain of chickpea is an important source of valuable proteins accounting 36-56% specifically for the purpose of human food consumption. Seeds of chickpea constitute (50-58%) carbohydrates, (15-22%) protein, (7-8%) moisture, and (3.8-10.20%) fat (Jukanti *et al.*, 2012). Morphologically chickpea is classified into two important classes i.e. Desi with smaller, darker seeds having more of a rough seed coat and Kabuli the larger, lighter-colored bean with a smoother coat (Knights and Hobson 2016). The content of protein in chickpea is about 18% (Kabuli: 18.4%; Desi: 18.2%), which is higher than other legumes such as lentils and field pea.

Because of rapid urbanisation and industrialization, India is in a precarious situation in which the count of people to feed will continue to increase at an astonishing speed. As a direct consequence, in order to boost grain production output, organic and inorganic farming methodologies must be employed depending upon the crop chosen. Second, due to the immediate stunning visuals of nitrogen fertilizer on seedlings and the greater price of rock phosphate and potassic fertilizers, most farmers prefer to apply only nitrogenous fertiliser to crops, resulting in an imbalance of nutrient consumption and soil nutrient depletion. Elevated agricultural production can be sustained by applying organic wastes and fertilisers sparingly.

Chickpea plays an important role in soil fertility because it fixes atmospheric nitrogen to available soil nitrogen (Gul *et al.*, 2011). Rhizobia bacteria play an important role in the improvement of agricultural ecosystem facilities due to their ability to form a symbiotic association with a wide range of leguminous plants and able to fix atmospheric nitrogen (Orrell and Bennett 2013). Root nodules of legumes develop a mutual and beneficial symbiotic partnership with *Rhizobium* which catalyzes nitrogen fixation from the atmospheric air and provides more amount of nitrogen to plants ultimately improving the soil health and growth of plants (Baginsky *et al.*, 2015).

Organic agriculture is an ancient form of agriculture in India. In traditional India, agriculture was entirely based on the use of organic practices, in which manure, pesticides etc. were obtained from animal and plant related waste. In 1950 and 1960 there was a sudden surge in the population so government increases the import of food grains from developed countries but for the increment in food grain production, the farmers adopted the green revolution in India. Natural and organic fertilizers were replaced by chemical fertilizers and locally made pesticides were replaced by chemical pesticides. In inorganic conditions, the use of high-yielding varieties integrated with high inputs has reached a situation which caused immense depletion in soil micronutrients as well as soil microorganism. The intensive use of chemical fertilizers in disproportion has led to a decline in soil organic matter, increase in salinity, poor product quality and an increased high risk of pests and diseases in crop (Bhardwaj *et al.,* 2020). Hence a sustainable system of agriculture like organic farming has been proposed as a possible alternative to inorganic farming to reduce the harmful environmental effects of agriculture on the ecosystem. Organic farming is a renewable, eco-friendly farming practice that is based on minimal use of off-farm inputs and management practices that restore, maintain and enhance ecological harmony. Organic farming could be less damaging to the environment than inorganic farming which may help in preserving natural resources in the long term such as soil quality, water quality, and fossil fuel (Hossard *et al.,* 2016).

As the popularity of organic farming is increasing, plant breeding concerns are however a bottleneck in the further development of varieties. Currently, organic farming largely depends upon varieties supplied by the inorganic farming system/plant breeding, even though organic farming conditions demand varieties with different characteristics than conventional varieties. In the developing countries like India, where organic movement is at the initial stage of development, varieties that are specifically bred for organic and low-input systems are almost nil. In developing countries, it is estimated that more than 95% of organic agriculture is based on crop varieties that were bred for the conventional high-input sector with selection in a conventional breeding program. It has been observed that such varieties lack important traits required under organic and low-input production conditions (Lammerts *et al*., 2002). This is primarily due to selection in conventional breeding programs being carried out in the background of high inorganic fertilizer and crop protection inputs.

To the best of our knowledge, no investigation has been conducted on the chickpea regarding comparative performance of chickpea genotypes under organic and chemical input conditions in the sandy loam soils of the mid hills of Himachal Pradesh. The main purpose of this study was to assess the chickpea genotypes for seed yield and related traits under organic *vis-à-vis* inorganic input conditions and thus to find out the important traits for selection under both the modules. The second aim of this investigation was to identify the promising and potential genotypes of chickpea for important yield traits under both the conditions for use in the future organic breeding programs of chickpea.

MATERIAL AND METHODS

A. Basic information about study site and soil analyses

Chickpea is an imperative crop amongst pulse crops. Accordingly, experiment was planned to assess the response of chickpea genotypes under two different nutrient management modules (organic vs. chemical) at the research farm of Organic Agriculture and Natural Farming, CSK HPKV, Palampur, Himachal Pradesh, India during two consecutive years 2017–18 and 2018–19.Geographically, the experimental farm is located at an elevation of about 1,290 m above mean sea level with 36º6′N latitude and 76º3′E longitude representing mid-hill the hill zone (Zone-II) of Himachal Pradesh and is characterized by a humid sub-temperate climate with high rainfall (2,500 mm per annum). The sowing of chickpeas was done in October for both the years under organic and inorganic conditions. The trial site had no previous known history of legume inoculation with any type of bio-inoculants. Before the commencement of experiment, composite soil samples from 0-15 cm depth were collected from organic and inorganic blocks separately. The samples were analyzed for different chemical properties and the results of the analysis have been given in Table 1. A perusal of data showed that the soil of the experimental field was acidic in nature under both the conditions. The soil was rated under high in organic carbon in organic input conditions whereas medium under chemical input conditions. The soils under both the conditions were medium in nitrogen, phosphorus and potassium.

B. Experimental design and treatment details

The experimental material comprised of 14 diverse chickpea germplasm lines including some land races and released cultivars of Northern Hill Zone. These 14 genotypes varying in their adaptability and yield potential including four checks were evaluated under conventional inorganic (E1) and low input organic (E2) conditions during 2017–18 and 2018–19.The two sets of material were raised in Randomized Block design with three replications. One set of the experimental material was raised in organic block of the farm while another set was raised in inorganic block on the same date. Thirteen genotypes *viz;* 113-P, 18-II, DKG-10, DKG-876, DKG-933, DKG-964, DKG-972, DKG-986, P-30-6, P-81, GPF-2, Him Chana-I, Him Chana-II and Palam Chana -I were raised in 3m lengths with line to line and plant to plant spacing of 30cm and 10cm sequentially. During the sowing time under organic farming conditions, vermicompost was applied at the rate of 5.0t/ha for providing nutrients and other components to the crop whereas under inorganic farming conditions N: P: K was put in the soil at the ratio of 30:60:30 Kg/ha during both the years.

C. Preparation of Vermicompost

Vermicompost was prepared by using heap method. A fine bed of 10 × 4 × 2 feet dimension was prepared by adding partially decomposed cow dung, dried leaves and other biodegradable wastes collected from fields and were distributed evenly in a layered manner. Another layers of chopped bio-waste and partially decomposed cow dung were added upto the height of 2 feet. The heap was covered with dry grass on the top and after 24 days, 4000 worms of *Eisenia foetida* species were introduced into the heap without disturbing it. Water was sprinkled regularly to maintain the moisture of the heap. Vermicompost got ready after 90 days and finally vermicompost was harvested by sieving it through 2-3mm sieve for final application.

Observations recorded. The data was recorded on five random competitive plants for each genotype across replications on yield and related traits except days to 50% flowering and days to 75% maturity, which were recorded on plot basis in both the years.

Phenological traits: Days to flowering. Total number of days taken from the date of sowing to the day when 50% plants showed flowering was recorded on five randomly selected plants.

Days to maturity

Total number of days taken from date of sowing to the date when 75% plants showed physiological maturity was recorded on five randomly selected plants.

Growth parameters :

The data was recorded on five random competitive plants for each genotype across replications on the following yield traits:

Plant height (cm). Height of five randomly selected plants from each plot was measured from the ground level to the top of the main stem at the time of maturity and averaged.

Number of primary branches per plant

The number of primary branches emerging directly from the main stem were recorded by counting five selected plants at the time of maturity and averaged.

Number of secondary branches per plant. The number of secondary branches emerging from the primary branches was counted in the randomly taken five plants.

Yield and related traits:

Pod length (cm). The length of the individual pod of randomly taken five plants was measured with vernier caliper.

Pod width (cm). The width of individual pod of randomly taken five plants was measured with vernier caliper.

Number of pods per plant. Number of pods per plant was recorded by counting the number of pods present in the randomly selected five plants at the time of maturity.

Number of seeds per pod. Number of seeds per pod were counted from five randomly selected pods in each of the selected plants and averaged.

100-seed weight (g). 100-seed weight was recorded in grams by weighing randomly selected 100 seeds from each genotype and replication and averaged.

Biological yield per plant (g). Sun dried plants from all the selected plants were separately weighted and averaged.

Harvest index (%) It was calculated by dividing seed yield per plant by biological yield per plant expressed as:

$$\text{H.I.} = \frac{\text{Seed yield per plant (g)}}{\text{Biological yield (g)}} \times 100$$

Seed yield per plant (g)

Selected plants were threshed and weight of the seeds was recorded and averaged.

Nodulation parameters:

Nodule number per plant. Nodule number was recorded from five randomly taken plants and then averaged.

Nodule fresh weight per plant (g). Nodules of the uprooted five random plants were washed and their fresh weight was recorded and averaged.

Nodule dry weight per plant (g). Nodules of the uprooted plants were oven dried at 70°C to constant weight and

dry weight was recorded.

Nitrogen fixation (ηmolesC_2H_4/Fresh weight of root in g/2.5hr/Plant). It was measured at flowering stage of crop growth and determined through Gas Liquid Chromatograph (GC). Data was recorded from one randomly selected plant.

METHOD

The roots with nodules were washed and placed in the vessel. Mouth of vessel was closed by rubber septum. The pre calculated quantity of C_2H_2 was injected with the help of syringe by removing equal quantity of air. The sample was incubated at desired temperature for two and half hour. After the incubation, a gas sample was removed for analysis. 0.1 ml of gas was removed with a needle and syringe and stored by putting the needle in the rubber cork. Gas chromatograph was calibrated for the range of C_2H_2 concentration expected and the gas was injected into chromatograph and finally the graph was taken

Calculations: The acetylene reduction activity is calculated by using the formula given by Postgate (1972)

$$\text{Acetylene reduction activity} = \frac{\text{Area of the peak} \times \text{Volume of the flask} \times 0.0006}{\text{Vol. of gas injected into GC} \times \text{Hours of incubation} \times \text{Fresh weight of root sample}}$$

Statistical analysis. The observations recorded as above for the various yield and yield contributing characters were subjected to the following statistical analysis.

Analysis of variance. The data for different characters was analyzed as per Panse and Sukhatme (1987).

Soil nutrient analysis. Before the commencement of experiment during Rabi 2017–18, composite soil samples from 0-15 cm depth were collected from all the three replications under organic and chemical input conditions. The samples were analyzed for different chemical properties and the results of the analysis have been given in Table 1. A perusal of data presented in Table 1 showed that the soil of the experimental field was acidic in nature under both the conditions. The soil was rated as high in organic carbon in organic input conditions whereas medium under chemical input conditions, medium in nitrogen, phosphorus and potassium under both conditions.

Table 1: Chemical characteristics of the experimental soil of organic and inorganic block.

Soil Characteristics	Organic block	Inorganic block	Analytical method employed
pH	4.5	4.7	1:2.5 Soil water suspension (Jackson 1973)
Organic carbon (%)	1.29	0.99	Wet digestion method (Walkley and Black 1934)
Available Nitrogen (kg/ha)	344.96	282.24	Alkaline permanganate method (Subbiah and Asija1956)
Available Phosphorus(kg/ha)	24.64	20.16	Olsen's method (Olsen *et al.*, 1954)
Available Potassium (kg/ha)	197.56	175.11	Ammonium acetate extraction method (AOAC 1990)

Statistical analysis. All data were analyzed by ANOVA with the statistical software package. The data were statistically analyzed as per Panse and Sukhatme (1987). The direct and indirect effects were measured as suggested by Dewey and Lu (1959). The coefficient of variation was calculated as per Burton and De Vane (1958).

RESULTS AND DISCUSSION

Analysis of variance. Analysis of variance (ANOVA) was carried out for different traits under low and high input conditions. All traits were found to be highly significant except nitrogen fixation under high input conditions, pod length and pod width under low input conditions (Table 2).

Mean performance

Phenological traits. Results of the two year experiment showed that under the organic treatments, the mean values for the genotypes ranged from 92.33 to 107.67 days and 182.67 to 192.67 days respectively for days to 50% flowering and days to 75% maturity. The genotype DKG-986 was found to be statistically at par with the check for days to 50% flowering.

Under inorganic conditions, the mean values of genotypes for days to 50% flowering and days to 75% maturity ranged from 98 to 126 days and 169 to 197 days 56.29 respectively. Only one genotype i.e. DKG-986 was found to be significantly early than the check for days to 75% maturity.

Growth Parameters. Plant height, primary branches/plant and secondary branches/plant varied from 73.50 cm to 89.20 cm, 2.60 to 4.20, and 8.07 to 13.53 respectively while pod length and width varied from 2.10 to 2.39cm and 0.81 to 0.86 cm respectively with the amendments of organic inputs. Genotype 18-II was found to be significantly superior over the best check for two traits i.e., primary branches per plant and secondary branches per plant.

With the use of inorganic inputs the mean value varied from 56.29 cm to 74.40 cm, 2.07 to 3.50 and 4.80 to 11.73 for plant height, primary branches/plant and secondary branches/plant. Pod length and width varied from 2.07 to 2.23cm and 0.77 to 0.84 cm respectively. Four genotypes i.e. 18-II, 113-P, P-30-6, and DKG-964 were found superior over the best check. Similar findings were reported in comparative studies in organic and inorganic conditions on wheat and lentil genotypes by Bhardwaj *et al.* (2019a; 2019b).

Nodulation parameters

With the use of organic inputs the mean value for nodule number, nodule fresh weight and nodule dry weight varied from 9.33 to 21.67, 0.22 gm to 1.48 gm, and 0.05 gm to 0.19 gm respectively. Nitrogen fixation which was non significant trait in the present study varied from 230.42-414.50ηmoles/plant. Two genotypes 18-II and DKG 10 were significantly superior to the best check for the above mentioned traits in the present investigation while P-30-6, DKG 876 and DKG-964 genotypes were found to be superior than the best check for nodule dry weight.

On the other side with the use of inorganic inputs, the mean value for nodule number, nodule fresh weight and nodule dry weight varied from 0.33 to 7.00, 0.03 gm to 0.85 gm, and 0.00 gm to 0.07 gm. None of the genotypes was found to be superior under inorganic conditions (shown in Fig. 1 and 2) for these traits. Nitrogen fixation varied from 105.30 to 677.68ηmoles/plant.

Nitrogen fixation though was non significant trait under both the conditions but all the genotypes fixed higher amount of nitrogen in organic input conditions as compared to the inorganic one. Nodules were healthy in organic farming having more fresh and dry weight as compared to the inorganic farming resulting in increased yield under the organic farming system. The results are in conformity with the findings of Tagore *et al.* (2013); Bidyarania *et al.* (2016); Priyadarsini *et al.* (2017).

Yield and its contributing traits. With the application of organic modules, the mean value for number of pods/plant and number of seeds/pod varied from 43.13 to 61.87 and 1.60 to 2.07 respectively. The mean values of 100 seed weight, biological yield/plant, harvest index and seed yield/plant varied from 2.76 to 4.08 g, 23.82 to 38.73 g, 27.06 to 54.20% and 6.49 to 21.06 g respectively. DKG 933 was superior for 100 seed weight while the DKG 964 and P-30-6 were found to be superior for harvest index and seed yield/plant to the best check.

With the use of inorganic fertilizers the mean value for pods/plant and seeds/pod varied from 28.20 to 39.13 and 1.47 to 2.00 respectively. On the other hand, the mean values for 100-seed weight, biological yield per plant, harvest index and seed yield ranged from 2.98 to 3.97 g, 40.50 to 55.00 g, 11.95 to 23.46% and 4.21 to 10.36g under inorganic input conditions.113-P, 18-II are found to be superior for 100-seed weight, harvest index and other contributing traits toward seed yield/plant while P-30-6 and DKG 964 were found to be superior to the best check for seed yield/plant.

Based upon the mean performance for seed yield/plant ,four genotypes were observed to be common under both organic and inorganic input conditions *viz*; 18-II, 113-P, DKG-964, P-30-6 which were found significantly superior to the best check, indicating broad non-system specific adaptation and the potential for selection of varieties capable of high yields across systems. Genotype DKG-933 which was ranked 5th under inorganic input conditions was the lowest yielder under organic input conditions ranking 12 among 14 genotypes. Similarly, among the released checks, Palam Chana-I which was the best check under organic input conditions was the lowest yielder under inorganic input conditions. The main reason behind wide difference for yield in genotypes under two systems attributes to healthy and more nodules in organic farming fixing more nitrogen as compared to the inorganic farming, hence higher yield is being recorded under the organic farming system. The results are in agreement with the findings of Tagore *et al.* (2013); Bidyarania *et al.* (2016); Priyadarsini *et al.* (2017).

Coefficient of variation. The observed PCV and GCV values were higher (>35%) for nodule number, nodule fresh weight, nodule dry weight, nitrogen fixation and seed yield/plant under both organic and inorganic input conditions. Moderate PCV and GCV (15-25%) were observed for primary branches/plant, secondary branches/plant, harvest index and seed yield/plant under inorganic input conditions whereas under organic input conditions the values were moderate for only primary branches and harvest index.

Heritability and Genetic Advance. Higher estimates of heritability (>60%) were observed for almost all the traits under the both conditions. Moderate heritability (40-60%) was observed for 100-seed weight and biological yield/plant under both conditions whereas pods/plant and seeds/pod only under organic input conditions. The genetic advance was found to be higher for pods/plant in inorganic input conditions whereas nodule number, nodule fresh weight, nodule dry weight, primary branches, secondary branches, harvest index, and seed yield/plant exhibited high genetic advance under both the conditions. High genetic advance coupled with high heritability was observed for nodule number, nodule fresh weight, nodule dry weight, and seed yield/plant under both conditions. Priyadarsini *et al.* (2017) also observed high heritability with high GA% over mean in case of nodule number/plant, nodule dry weight/plant, number of pods/plant, 100-seed weight, harvest index, and seed yield/plant.

Correlation and Path Analysis. Correlation and path coefficient analysis has revealed some interesting facts about different farming conditions. Exposure to low input or organic farming conditions may induce positive or negative correlations among traits due to the expression of new genes, the variances and co-variances among traits are changed and correlation values show a congenial effect of low input conditions that helps in selection among different traits under organic farming conditions in making direct and indirect contributions of component characters towards seed yield.

Correlation Studies. Under organic input conditions as depicted in Table 8, seed yield/plant was significantly positively correlated with secondary branches/ plant, pods/plant, nodule number/plant, nodule fresh weight/plant, nodule dry weight/plant, harvest index, and biological yield/plant while under inorganic input conditions, seed yield/plant was significantly positively correlated with primary branches /plant, secondary branches/plant, pods/plant, 100-seed weight, harvest index, and biological yield/plant. Some traits are similar in both the farming system, contributing to high yield. Similar observations were also made by other workers like Raval and Dobaria (2003); Vekariya *et al*. (2008); Priyadarsini *et al*. (2017) Ghaffar *et al*. (2018); Dawane *et al*. (2020); Raju *et al*. (2021); Kumar *et al*. (2021) where seed yield was positively and significantly correlated with biological yield per plant, 100 seed weight, number of pods per plant, harvest index, number of secondary branches/plants.

Path Analysis. Path analysis showed in Table 9 represents a high magnitude of direct effects for secondary branches/plant, harvest index, nodule number, biological yield/plant, pods/plant, seeds/pod, and nodule dry weight under organic input conditions. Thus, under organic input conditions these traits can be selected as selection parameters for high yield. In contrast to organic input conditions, under inorganic input conditions secondary branches, primary branches, pods/plant, and 100-seed weight showed high correlation and high direct effect on seed yield. Harvest index and biological yield/plant showed high correlation values and high indirect effects via secondary branches/plant, nitrogen fixation, and pods/plant.

The results on correlation and path studies indicate that different selection parameters operate for yield improvement under both the farming conditions. Thus, the traits *viz*; primary branches/plant, secondary branches/plant, pods/plant, 100-seed weight, harvest index and biological yield/plant are to be considered as selection criteria for high yield in high input conditions while secondary branches, pods/plant, nodule number, nodule fresh weight, nodule dry weight, harvest index, and biological yield/plant are important selection criteria for low input conditions. Some traits do not show any type of interaction with the change in the farming system like secondary branches per plant, pods per plant, harvest index and biological yield/plant as these traits show a positive correlation with yield under both the conditions showing their importance for selecting high yielding genotypes irrespective of the condition. Some others expressed differently under varied input conditions like primary branches per plant which proved to be an important selection criteria only under inorganic conditions having significant positive correlation with yield and was non significant under organic conditions. Similar findings of varied response of genotypes under different input conditions was observed by Bhardwaj *et al.* (2019a; 2019b) in lentil and wheat.

To ascertain such facts simple correlations (Table 10) were also worked out between organic and inorganic input conditions which showed a high correlation coefficient between the two conditions for days to 50% flowering, secondary branches/plant pods/plant, and harvest index, indicating the absence of genotype and input interaction for these traits. Thus, there is no need for separate breeding programs for improving these traits. However, for the traits like seeds/pod, 100-seed weight, biological yield/plant, pod length, pod width, plant height, days to 75% maturity, and nodule number, which exhibited positive correlations, of lower magnitude and for traits such as primary branches/plant, nodule fresh weight, nodule dry weight and nitrogen fixation which exhibit negative correlations depicted interaction of genotype and input, suggesting the need of separate breeding program for the improvement of these traits. Similar results were also to those obtained by Sood and Sood (2001) for the effects of cropping systems on some genetic parameters in soybeans and justified separate breeding programs for each cropping system. Bhardwaj *et al*. (2012) made comparative studies on the correlation of yield and yield components under organic vis-a-vis non-organic input conditions in the wheat and found that correlation patterns under the two different conditions indicated the influence of genetic interactions.

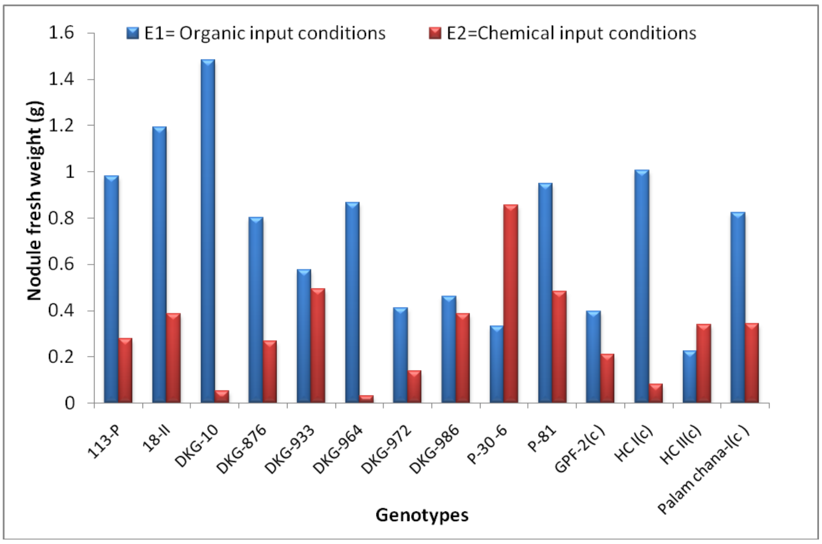

Fig. 1. Variation in chickpea genotypes for nodule fresh weight Organic and Inorganic input conditions.

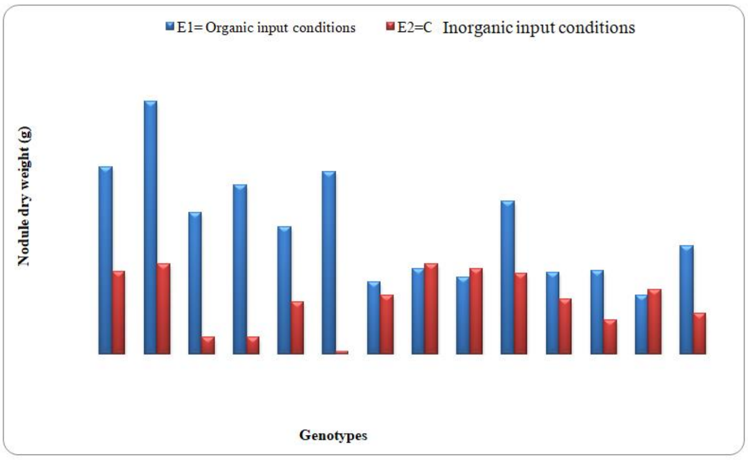

Fig. 2. Variation in chickpea genotypes for nodule dry weight Organic and Inorganic input conditions.

Variation in root and plant growth of genotype DKG-964 under organic and inorganic input conditions.

Table 2: Analysis of variance for different traits in chickpea under low and high input conditions.

Traits	Mean sum of squares					
Source	Replication		Treatment		Error	
Df	2		13		26	
	E_1	E_2	E_1	E_2	E_1	E_2
Days to 50 % flowering	1.88	2.38	72.86*	188.29*	1.19	0.77
Days to 75 % maturity	0.07	0.67	18.41*	141.71*	0.94	0.54
Plant height	59.49	3.18	54.42*	86.32*	7.07	1.10
Primary branches/plant	0.16	0.20	0.69*	0.62*	0.11	0.04
Secondary branches/plant	2.39	1.08	5.53*	10.54*	0.56	0.19
Pod length	0.03	0.01	0.01	0.01*	0.01	0.01
Pod width	0.01	0.01	0.01	0.02*	0.01	0.01
Pods/ plant	6.13	13.43	69.07*	40.53*	12.98	2.09
Seeds/ pod	0.11	0.05	0.06*	0.07*	0.02	0.03
Nodule number	2.95	0.45	43.37*	16.34*	3.39	0.67
Nodule fresh weight	0.01	0.01	0.39*	0.14*	0.07	0.01
Nodule dry weight	0.01	0.01	0.05*	0.01*	0.01	0.01
Nitrogen fixation	32124.59	25555.74	23086.89	60482.50	22378.20	58968.90
100-seed weight	0.05	0.01	0.24*	0.26*	0.06	0.05
Biological yield/ plant	0.41	2.31	39.01*	34.86*	9.39	10.69
Harvest index	20.76	3.63	177.35*	34.68*	23.96	2.48
Yield/plant	1.01	1.86	36.26*	7.00*	3.93	0.77

E_1= Low or Organic input conditions E_2= High or Inorganic input conditions

Table 3: Mean performances of chickpea genotypes for phenological traits under Organic and chemical input conditions over years.

Traits	Days to 50 % flowering		Days to 75 % flowering	
Genotypes	E_1	E_2	E_1	E_2
113-P	96.00	107.33	191.67	196.33
18-II	104.33	114.67	187.33	196.00
DKG-10	100.67	118.00	188.33	192.33
DKG-876	104.00	115.67	187.33	193.00
DKG-933	97.33	110.67	190.00	190.67
DKG-964	106.67	126.00	187.67	197.00
DKG-972	105.33	108.67	186.00	193.67
DKG-986	93.00	101.67	188.33	169.00
P-30 -6	98.67	110.33	187.33	190.33
P-81	98.33	117.33	192.67	192.33
GPF-2 (c)	100.00	112.67	189.00	195.00
HC-1 (c)	104.33	117.00	185.67	191.33
HC-II (c)	107.67	125.67	188.00	190.33
Palam chana-I (c)	92.33	98.00	182.67	188.00
Mean	100.62	113.12	188.00	191.10
SE(m)±	0.63	0.51	0.56	0.42
C.D. (5%)	1.84	1.48	1.64	1.24
C.V (%)	1.08	0.77	0.52	0.38

E_1= Low or Organic input conditions E_2= High or Inorganic input conditions

Table 4: Mean performances of chickpea genotypes for growth parameters under Organic and chemical input conditions over years.

Traits	Plant height (cm)		Primary branches/plant		Secondary branches/plant		Pod length(cm)		Pod width(cm)	
Genotypes	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
113-P	82.48	74.02	3.20	3.53	12.53	10.47	2.25	2.18	0.83	0.82
18-II	89.20	74.33	4.20	2.80	13.53	11.73	2.22	2.23	0.86	0.84
DKG-10	73.50	61.15	3.13	2.93	10.47	8.07	2.29	2.19	0.83	0.55
DKG-876	84.46	71.86	3.20	2.40	9.80	6.07	2.27	2.23	0.85	0.84
DKG-933	87.33	71.13	3.67	2.40	9.73	9.07	2.39	2.20	0.81	0.84
DKG-964	78.50	71.31	2.80	2.07	10.73	10.07	2.31	2.11	0.86	0.78
DKG-972	81.83	67.76	3.27	2.60	10.53	8.53	2.29	2.09	0.81	0.81
DKG-986	80.31	74.40	2.60	3.07	9.73	9.47	2.34	2.13	0.83	0.80
P-30 -6	83.48	66.17	3.73	3.20	10.27	10.13	2.30	2.17	0.81	0.83
P-81	85.07	67.99	4.00	2.27	8.07	6.93	2.21	2.13	0.86	0.82
GPF-2 (c)	84.00	74.40	3.60	2.73	9.00	8.00	2.24	2.07	0.82	0.82
HC-1 (c)	84.37	67.05	3.13	2.20	9.80	8.40	2.23	2.17	0.85	0.83
HC-II (c)	76.75	66.40	2.67	3.20	9.67	9.20	2.21	2.13	0.83	0.77
Palam chana-I (c)	78.37	56.29	3.07	3.27	10.47	4.80	2.10	2.14	0.84	0.77
Mean	82.12	68.88	3.31	2.76	10.31	8.64	2.26	2.16	0.84	0.79
SE(m)±	1.54	0.61	0.19	0.12	0.43	0.25	0.06	0.01	0.02	0.01
C.D. (5%)	4.49	1.77	0.55	0.35	1.27	0.73	NS	0.03	NS	0.02
C.V (%)	3.24	1.52	9.85	7.53	7.28	5.03	4.33	0.86	3.27	1.77

E_1= Low or Organic input conditions E_2= High or Inorganic input conditions

Table 5: Mean performances of chickpea genotypes different nodulation parameters under Organic and chemical input conditions pooled over years.

Traits	Nodule number		Nodule fresh weight (g)		Nodule dry weight (g)		Nitrogen fixation (η moles)	
Genotypes	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
113-P	15.67	7.00	0.98	0.28	0.14	0.06	371.76	105.30
18-II	21.33	6.00	1.19	0.39	0.19	0.07	403.25	203.45
DKG-10	21.67	2.67	1.48	0.05	0.11	0.01	315.67	192.59
DKG-876	15.00	5.33	0.80	0.27	0.13	0.01	260.75	155.88
DKG-933	11.33	2.33	0.58	0.49	0.10	0.04	230.42	200.78
DKG-964	14.33	0.33	0.87	0.03	0.14	0.00	509.57	140.54
DKG-972	11.00	3.67	0.41	0.14	0.06	0.05	341.80	121.04
DKG-986	11.33	6.67	0.46	0.38	0.07	0.07	231.47	278.34
P-30 -6	17.33	5.33	0.95	0.48	0.12	0.06	247.32	294.30
P-81	13.33	2.67	0.40	0.21	0.06	0.04	396.10	222.68
GPF-2 (c)	13.67	7.00	0.33	0.85	0.06	0.07	347.73	677.68
HC-1 (c)	12.67	1.00	1.01	0.08	0.06	0.03	399.67	281.45
HC-II (c)	9.33	1.67	0.22	0.34	0.05	0.05	414.50	228.40
Palam chana-I (c)	10.33	6.00	0.82	0.34	0.08	0.03	217.16	136.97
Mean	14.17	4.12	0.75	0.31	0.10	0.04	334.80	231.39
SE(m)±	1.06	0.47	0.05	0.01	0.01	0.01	86.37	140.20
C.D. (5%)	3.11	1.37	0.15	0.03	0.02	0.01	NS	NS
C.V (%)	12.99	19.69	11.85	6.42	14.27	18.49	44.68	104.95
E_1= Low or Organic input conditions E_2 = High or Inorganic input conditions								

Table 6: Mean performances of chickpea genotypes for yield and related traits under Organic and chemical input conditions pooled over years.

Traits	Pods/ plant		Seeds/ pod		100-seed weight(g)		Biological yield/ plant (g)		Harvest index (%)		Seed yield/plant (g)	
Genotypes	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
113-P	59.13	38.67	1.93	1.73	3.32	3.94	33.66	48.33	44.34	22.76	15.03	10.30
18-II	61.87	39.13	2.07	2.00	3.51	3.97	30.89	55.00	38.60	23.46	21.06	10.36
DKG-10	54.33	31.27	1.60	1.67	3.14	3.29	33.44	44.33	36.40	17.15	11.89	7.85
DKG-876	52.53	28.20	1.67	1.60	3.33	3.23	31.63	43.67	35.65	14.33	11.29	7.73
DKG-933	47.67	35.93	1.67	1.53	4.08	3.13	30.87	46.33	31.79	20.16	9.87	9.18
DKG-964	56.00	36.60	1.67	1.93	3.30	3.55	38.73	47.00	54.20	21.74	15.02	9.42
DKG-972	55.33	32.07	1.80	1.47	3.37	3.33	33.90	44.67	39.85	19.02	13.56	8.28
DKG-986	51.40	35.87	1.93	1.73	3.49	3.21	28.67	45.67	35.34	20.10	10.25	9.16
P-30 -6	55.80	38.07	1.87	1.87	3.43	3.14	29.01	47.33	50.80	20.53	14.69	10.26
P-81	43.13	30.13	1.93	1.67	3.25	2.98	23.82	42.67	27.06	13.62	6.49	5.96
GPF-2 (c)	47.67	31.27	1.60	1.67	3.36	3.13	32.86	44.33	27.25	18.44	7.83	7.07
HC-1 (c)	53.33	31.40	1.73	1.73	3.16	3.22	31.05	44.33	37.62	18.64	10.72	7.22
HC-II (c)	53.07	33.47	1.80	1.73	2.76	3.25	30.38	45.00	37.43	19.88	10.38	7.90
Palam chana-I (c)	54.73	29.07	1.73	1.53	3.47	3.31	36.69	40.00	41.35	11.95	11.11	4.21
Mean	53.29	33.65	1.79	1.71	3.36	3.34	31.83	45.62	38.41	18.70	12.08	8.20
SE(m)±	2.08	0.83	0.08	0.10	0.14	0.13	1.77	1.89	2.83	0.91	1.14	0.51
C.D. (5%)	6.08	2.44	0.24	0.29	0.40	0.38	5.17	5.52	8.26	2.66	3.34	1.48
C.V (%)	6.76	4.30	8.04	10.17	7.08	6.69	9.63	7.17	12.74	8.42	16.02	10.32
E_1= Low or Organic input conditions E_2= High or Inorganic input conditions												

Table 7: Estimates of parameters of variability for yield and related traits in chickpea genotypes.

Traits	Mean ±S.E(m)		Range		PCV (%)		GCV (%)		Heritability h²bs (%)		Expected GA	
	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
Days to 50 % flowering	100.62±0.63	113.12±0.51	93.00-107.67	98.00-126.00	4.98	7.03	4.86	6.99	95.26	98.79	9.77	14.31
Days to 75 % maturity	188.00±0.56	191.10±0.42	182.67-192.67	169.00-197.00	1.38	3.61	1.28	3.59	86.06	98.87	2.45	7.35
Plant height	82.12±1.54	68.88±0.61	73.50-89.20	56.29-74.40	5.82	7.89	4.84	7.74	69.07	96.27	8.28	15.64
Primary branches/plant	3.31±0.19	2.76±0.12	2.60-4.20	2.07-3.53	16.58	17.58	13.34	15.89	64.69	81.68	22.10	29.58
Secondary branches/plant	10.31±0.43	8.64±0.25	8.07-13.53	4.80-11.73	14.45	21.56	12.48	20.96	74.63	94.55	22.21	41.99
Pod length	2.26±0.06	2.16±0.01	2.10-2.39	2.07-2.23	4.67	2.31	1.75	2.15	13.99	86.21	1.35	4.11
Pod width	0.84±0.02	0.79±0.01	0.81-0.86	0.55-0.84	3.56	9.63	1.41	9.47	15.59	96.61	1.14	19.18
Pods / plant	53.29±2.08	33.65±0.83	43.13-61.87	28.20-39.13	10.56	11.47	8.11	10.64	59.02	85.98	12.84	20.32
Seeds/ pod	1.79±0.08	1.70±0.10	1.60-2.07	1.47-2.00	10.38	12.18	6.57	6.70	40.09	30.27	8.57	7.59
Nodule number	14.17±1.06	4.12±0.47	9.33-	0.33-	28.86	58.89	25.77	55.51	79.73	88.83	47.40	107.76

			21.67	7.00								
Nodule fresh weight	0.75±0.05	0.31±0.01	0.22-1.48	0.03-0.85	49.62	70.46	48.18	70.16	94.29	99.17	96.38	143.93
Nodule dry weight	0.10±0.01	0.04±0.01	0.05-0.19	0.00-0.07	45.26	54.09	42.95	50.83	90.07	88.31	83.98	98.40
Nitrogen fixation	334.80±86.37	231.39±140.20	217.16-509.57	105.30-677.68	44.92	105.40	4.59	9.71	1.05	0.85	0.97	1.84
100-seed weight	3.36±0.14	3.34±0.13	2.76-4.08	2.98-3.97	10.22	10.31	7.37	7.85	51.99	57.97	10.95	12.31
Biological yield/ plant	31.83±1.77	45.62±1.89	23.82-38.73	40.00-55.00	13.79	9.49	9.87	6.22	51.27	42.97	14.56	8.40
Harvest index	38.41±2.83	18.70±0.91	27.06-54.20	11.95-23.46	22.56	19.44	18.62	17.52	68.10	81.23	31.65	32.53
Seed yield/plant	12.08±1.14	8.20±0.51	6.49-21.06	4.21-10.36	30.99	19.86	26.54	16.97	73.30	73.00	46.80	29.86

E_1= Low or Organic input conditions **E_2= High or Inorganic input conditions**

PCV: Phenotypic coefficient of variation GCV: Genotypic coefficient of variation h^2bs: Heritability in broad sense GA: Genetic advance (% of mean)

Table 8: Pooled estimates of correlation coefficients among seed yield and related traits of chickpea under Organic and Chemical input conditions at the phenotypic level.

Traits		**Days to 75 % maturity**	**Plant height**	**Primary branches /plant**	**Secondary branches/ plant**	**Pod length**	**Pod width**	**Pods/ plant**	**Seeds/ pod**	**Nodule number**	**Nodule fresh weight**	**Nodule dry weight**	**Nitrogen fixation**	**100-seed weight**	**Biological yield/ plant**	**Harvest index**	**Seed yield/ plant**
Days to 50 % flowering	E_1	-0.11	0.00	-0.04	0.09	0.00	0.14	0.22	-0.11	0.10	0.00	0.11	0.37*	-0.37*	0.15	0.19	0.28
	E_2	0.49*	0.12	-0.46*	-0.05	0.02	-0.17	-0.08	0.30	-0.68*	-0.33*	-0.38*	0.02	0.01	-0.02	-0.01	-0.04
Days to 75 % maturity	E_1		0.19	0.21	-0.11	0.23	-0.09	-0.32*	0.15	0.15	-0.15	0.04	0.12	0.06	-0.37*	-0.34*	-0.28
	E_2		0.00	-0.24	0.20	0.09	0.03	0.31*	0.08	-0.22	-0.12	-0.22	-0.03	0.28	0.20	0.20	0.19
Plant height	E_1			0.54*	0.10	0.05	0.02	-0.12	0.28	0.03	-0.08	0.21	0.02	0.39*	-0.29	-0.20	0.14
	E_2			-0.19	-0.04	0.07	0.54*	-0.03	0.27	0.26	0.33*	0.38*	0.14	0.26	0.17	-0.08	-0.07
Primary branches/plant	E_1				0.10	0.10	-0.04	-0.08	0.17	0.35*	0.10	0.27	0.03	0.24	-0.35*	-0.23	0.09
	E_2				0.37*	0.05	-0.20	0.30	0.02	0.53*	0.29	0.45*	-0.04	0.26	0.29	0.28	0.31*
Secondary branches/plant	E_1					-0.02	0.10	0.75*	0.36*	0.45*	0.54*	0.57*	0.10	0.13	0.35*	0.42*	0.77*
	E_2					0.26	-0.13	0.87*	0.45*	0.20	-0.23	0.04	-0.20	0.69*	0.68*	0.92*	0.83*
Pod length	E_1						-0.12	-0.08	-0.20	0.06	0.04	-0.01	0.13	0.27	-0.19	-0.03	-0.18
	E_2						0.02	0.12	0.27	0.07	-0.16	-0.16	-0.20	0.27	0.33*	0.31*	0.28
Pod width	E_1							0.00	0.25	0.10	0.14	-0.01	0.28	-0.18	-0.05	-0.04	0.13
	E_2							-0.05	0.04	0.21	0.38*	0.38*	0.08	0.05	0.05	-0.14	-0.11
Pods / plant	E_1								0.29	0.34*	0.48*	0.49*	-0.14	0.01	0.32*	0.59*	0.71*
	E_2								0.35*	0.18	-0.27	0.09	-0.25	0.64*	0.66*	0.81*	0.77*
Seeds/ pod	E_1									0.10	-0.07	0.25	-0.09	-0.01	-0.29	0.06	0.33*
	E_2									0.03	-0.03	-0.04	-0.15	0.44*	0.40*	0.38*	0.26
Nodule number	E_1										0.65*	0.61*	-0.01	-0.02	0.03	0.15	0.47*
	E_2										0.58*	0.56*	0.14	0.15	0.16	0.06	0.01
Nodule fresh weight	E_1											0.47*	0.14	0.12	0.33*	0.34*	0.43*
	E_2											0.61*	0.43*	-0.16	-0.07	-0.39*	-0.35*
Nodule dry weight	E_1												-0.02	0.13	0.21	0.45*	0.63*
	E_2												0.27	0.13	0.19	-0.11	-0.05
Nitrogen fixation	E_1													-0.28	0.05	0.03	0.04
	E_2													-0.25	-0.32*	-0.41*	-0.42*
100-seed weight	E_1														-0.05	-0.05	-0.06
	E_2														0.67*	0.65*	0.65*
Biological yield/ plant	E_1															0.42*	0.38*
	E_2															0.66*	0.63*
Harvest index	E_1																0.62*
	E_2																0.84*

***Significant at a 5% level of significance**

E_1= Low or Organic input conditions **E_2= High or Inorganic input conditions**

Table 9: Pooled estimates of direct and indirect effects of different traits on seed yield of chickpea under Organic and Chemical input conditions at the phenotypic level.

Traits		**Days to 50% flowering**	**Days to 75 % maturity**	**Plant height**	**Primary branches/ plant**	**Secondary branches/ plant**	**Pod length**	**Pod width**	**Pods / plant**	**Seeds/ pod**	**Nodule number**	**Nodule fresh weight**	**Nodule dry weight**	**Nitrogen fixation**	**100-seed weight**	**Biological yield/ plant**	**Harvest index**	**Correlation with grain yield**
Days to 50 % flowering	E_1	**0.06**	0.01	0.00	0.00	0.03	0.00	0.00	0.02	-0.00	0.03	0.00	0.01	0.00	0.04	0.02	0.06	0.28
	E_2	**-0.14**	0.00	0.02	-0.06	-0.04	0.00	0.00	-0.01	-0.06	0.27	-0.02	0.01	-0.01	0.00	0.00	0.00	-0.04
Days to 75 % maturity	E_1	-0.01	**-0.12**	0.04	0.00	-0.04	-0.02	0.00	-0.03	0.01	0.04	0.02	0.00	0.00	-0.01	-0.05	-0.11	-0.28
	E_2	-0.07	**0.01**	0.01	-0.03	0.17	0.01	0.00	0.04	-0.02	0.09	-0.01	0.01	0.01	0.02	-0.01	-0.02	0.19
Plant height	E_1	0.00	-0.03	**0.23**	0.01	0.04	0.00	0.00	-0.01	0.02	0.01	0.01	0.01	0.00	-0.04	-0.04	-0.06	0.14
	E_2	-0.01	0.00	**0.16**	-0.02	-0.04	0.01	0.00	0.00	-0.05	-0.10	0.03	-0.01	-0.04	0.02	-0.01	0.01	-0.07
Primary branches/plant	E_1	0.00	-0.02	0.12	**0.01**	0.04	-0.01	0.00	-0.01	0.01	0.10	-0.02	0.01	0.00	-0.03	-0.04	-0.07	0.09
	E_2	0.06	0.00	-0.03	**0.13**	0.32	0.00	0.00	0.03	0.00	-0.21	0.03	-0.01	0.01	0.02	-0.02	-0.02	0.31*
Secondary branches/ plant	E_1	0.01	0.02	0.02	0.00	**0.40**	0.00	0.00	0.07	0.02	0.12	-0.09	0.03	0.00	-0.02	0.04	0.13	0.77*
	E_2	0.01	0.00	-0.03	0.05	**0.87**	0.03	0.00	0.10	-0.09	-0.08	-0.02	0.00	0.05	0.06	-0.04	-0.08	0.83*
Pod length	E_1	0.00	-0.03	0.00	0.00	-0.01	**-0.07**	0.00	-0.01	-0.01	0.02	-0.01	0.00	0.00	-0.03	-0.02	-0.01	-0.18
	E_2	0.00	0.00	0.01	0.01	0.23	**0.10**	0.00	0.01	-0.05	-0.03	-0.01	0.00	0.05	0.02	-0.02	-0.04	0.28
Pod width	E_1	0.01	0.01	0.01	0.00	0.04	0.01	**0.03**	0.00	0.02	0.03	-0.02	0.00	0.00	0.02	-0.02	-0.01	0.13
	E_2	0.02	0.00	0.09	-0.03	-0.11	0.00	**0.00**	-0.01	-0.01	-0.08	0.04	-0.01	-0.02	0.00	0.00	0.01	-0.11
Pods/	E_1	0.01	0.04	-0.03	0.00	0.30	0.01	0.00	**0.10**	0.02	0.09	-0.08	0.02	0.00	0.00	0.04	0.19	0.71*

plant	E_2	0.01	0.00	0.00	0.04	0.75	0.01	0.00	**0.11**	-0.07	-0.07	-0.04	0.00	0.07	0.05	-0.04	-0.07	0.77*
Seeds/ pod	E_1	-0.02	-0.02	0.06	0.00	0.14	0.01	0.01	0.03	**0.07**	0.03	0.01	0.01	0.00	0.00	-0.04	0.02	0.33*
	E_2	-0.04	0.00	0.04	0.00	0.39	0.03	0.00	0.04	**-0.20**	-0.02	0.00	0.00	0.04	0.04	-0.03	-0.03	0.26
Nodule number	E_1	0.01	-0.02	0.01	0.00	0.18	0.00	0.00	0.03	0.01	**0.28**	-0.11	0.03	0.00	0.00	0.00	0.05	0.47*
	E_2	0.10	0.00	0.04	0.07	0.18	0.01	0.00	0.02	-0.01	**-0.40**	0.06	-0.01	-0.04	0.01	-0.01	0.00	0.01
Nodule fresh weight	E_1	0.00	0.02	-0.02	0.00	0.21	0.00	0.00	0.05	0.00	0.18	**-0.17**	0.02	0.00	-0.01	0.04	0.11	0.43*
	E_2	0.03	0.00	0.05	0.04	-0.20	-0.01	0.00	-0.03	0.01	-0.24	**0.10**	-0.01	-0.11	-0.01	0.00	0.03	-0.35*
Nodule dry weight	E_1	0.01	-0.03	0.05	0.00	0.23	0.00	0.00	0.05	0.02	0.17	-0.08	**0.05**	0.00	-0.01	0.03	0.14	0.63*
	E_2	0.05	0.00	0.06	0.06	0.03	-0.02	0.00	0.01	0.00	-0.22	0.06	**-0.02**	-0.07	0.01	-0.01	0.01	-0.05
Nitrogen fixation	E_1	0.02	-0.02	0.01	0.00	0.04	-0.02	0.01	-0.01	-0.01	0.00	-0.02	0.00	**-0.01**	0.03	0.01	0.01	0.04
	E_2	0.02	0.00	0.02	-0.01	-0.17	-0.02	0.00	-0.03	0.03	-0.06	0.04	-0.01	**-0.26**	-0.02	0.02	0.03	-0.42*
100-seed weight	E_1	-0.02	-0.02	0.09	0.00	0.05	-0.02	-0.01	0.00	0.00	-0.01	-0.02	0.01	0.00	**-0.10**	-0.01	-0.02	-0.06
	E_2	0.00	0.00	0.04	0.03	0.60	0.03	0.00	0.07	-0.09	-0.06	-0.02	0.00	0.06	**0.08**	-0.04	-0.05	0.65*
Biological yield/ plant	E_1	0.03	0.05	-0.07	0.00	0.14	0.01	0.00	0.03	-0.02	0.01	-0.06	0.01	0.00	0.00	**0.12**	0.13	0.38*
	E_2	0.00	0.00	0.03	0.04	0.59	0.03	0.00	0.08	-0.08	-0.07	-0.01	0.00	0.08	0.05	**-0.06**	-0.05	0.63*
Harvest index	E_1	0.01	0.05	-0.04	0.00	0.17	0.00	0.00	0.06	0.00	0.04	-0.06	0.02	0.00	0.01	0.05	**0.31**	0.62*
	E_2	0.00	0.00	-0.01	0.04	0.79	0.03	0.00	0.09	-0.08	-0.02	-0.04	0.00	0.11	0.05	-0.04	**-0.08**	0.84*

Residual effects (R), Organic= 0.15865, Inorganic = 0.15910; *Significant at 5% level of significance; Diagonal bold values denote direct effects and remaining indirect effects

Table 10: Pooled simple correlation for different traits under organic and chemical input conditions.

Sr. No.	Traits	Correlation values
1.	Days to 50% flowering	0.82
2.	Days to 75% maturity	0.12
3.	Plant height	0.56
4.	Primary branches per plant	-0.17
5.	Secondary branches per plant	0.87
6.	Pod length	0.12
7.	Pod width	0.09
8.	Pods per plant	0.90
9.	Seeds per pod	0.43
10.	Nodule number	0.17
11.	Nodule fresh weight	-0.41
12.	Nodule dry weight	-0.05
13.	Nitrogen fixation	-0.03
14.	100-seed weight	0.02
15.	Biological yield per plant	0.35
16.	Harvest index	0.79
17.	Seed yield per plant	0.58

CONCLUSIONS

For breeding of varieties suitable for organic agriculture traits like secondary branches, pods/plant, nodule number, nodule fresh weight, nodule dry weight, harvest index and biological yield/plant are an important selection criteria whereas for inorganic input conditions primary branches/plant, secondary branches/plant, pods/plant, 100-seed weight, harvest index and biological yield/plant should be used as selection criteria. Keeping in view, the varied performance of genotypes under both the systems and the correlation pattern it can be concluded that organic agriculture needs a separate breeding program for the development of organic input responsive varieties. Similar genotypes are used for both conditions but in organic input conditions they behave better than the inorganic input conditions and their expression was different in both the conditions due to the difference in expression of genes. These results indicate the yield evaluations must be done separately in both systems to identify environment-specific as well as relatively few broadly adapted genotypes because the broadly adapted genotypes are the exception rather than the rule. There is evidence that change in conditions can influence genetic interactions among traits as well as genetic variance in traits themselves.

REFERENCES

AOAC (1990). Official Methods of Analysis: Association of Analytical Chemists (16th Ed.). Arlington Virginia, USA.

Baginsky, C., Brito, B., and Scherson, R. (2015). Genetic diversity of Rhizobium from nodulating beans grown in a variety of Mediterranean climate soils of Chile. *Arch Microbiol.*, *197*, 419-429.

Bhardwaj, A. K., Rajwar, D., Basak, N., Bhardwaj, N., Chaudhari, S. K., Bhaskar, S. and Sharma, P. C. (2020). Nitrogen minieralization and availability at critical stages of rice (*Oryza sativa*) crop, and its relation to soil biology activity and crop productivity under major nutrient management systems. *Journal of Soil Science and Plant Nutrition*, *20*, 1238-1248.

Bhardwaj, N., Rana, V. and Saini, J. P. (2012). Correlation analysis of yield and yield components in wheat under organic vis-a-vis inorganic input conditions. Crop Improvement (Special Issue). pp 253-254.

Bhardwaj, N., Kaur, J. J., Lata, S. and Saini, J. P. (2019a). Differential response of wheat in organic and inorganic input conditions. An abstract in the 4th International Group Meeting on Wheat Productivity Enhancement through Climate Smart Practices held at CSKHPKV, Palampur from 14.2.2019 to 16.2.2019. pp 125.

Bhardwaj, N., Kaur, J. J., Upadhyay, R. G. and Saini, J. P. (2019b). Evaluation of lentil genotypes under organic vis-a-vis non-organic input conditions. An abstract in the National Conference on Organic & Natural Farming, A Toll for Sustainable Agriculture & Economic Development Organized by Organic Agriculture Society

of India at CSKHPKV, Palampur from 28.5.19 to 29.5.2019. pp 35
Bidyarania, N., Prasannaa, R., Babua, S., Hossainb and Saxenaaa, A.K. (2016). Enhancement of plant growth and yields in Chickpea through novel cyanobacterial and biofilmed inoculants. *Elsevier, 188*, 97-105.
Burton, G. M. and DeVane, E. H. (1958). Estimating heritability in tall Fescue (*Festuca arundinacea)* from replicated clonal material. *Agronomy Journal, 45*, 310-314.
Dawane, J. K., Jahagirdar, J. E. and Shedge, P. J. (2020). Correlation Studies and Path Coefficient Analysis in Chickpea (*Cicer arietinum* L.). *Int. J. Curr. Microbiol. App. Sci., 9*, 1266-1272.
Dewey, D. R. and Lu, K. H. (1959). A Correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal, 51*, 510-515.
Ghaffar, A., Hussain, N., Aslam, M., Irshad, M., Nadeem, M., Hussain, K., Parveen, Z. and Abbas, M. (2018). Correlation and path coefficient analysis study for yield improvement in chickpea (*Cicer arietinum* L.). *International journal of current agricultural sciences*, *5*, 293-295.
Gul, R., Khan, H., Sattar, S., Farhatullah, M. F., Shadman, K. B. S. A., Khattak, S. H., Arif, M. and Ali, A. (2011). Comparison among nodulated and non-nodulated chickpea genotypes. *Sarhad Journal of Agriculture, 27,* 577-581.
Hossard, L., Archer, D. W., Bertrand, M., David, C., Debaeke, P., Ernfors, M., Jeuffroy, M.H., Munier- Jolain, N., Nilsson, C., Sanford, G. R., Snapp, S.S., Jensen, E. S. and Makowski, D. (2016). A meta-analysis of maize and wheat yields in low-inputs vs. conventional and organic systems. *Agronomy Journal*, *108*, 1155-1167.
Jackson, M.L. (1973). Soil Chemical Analysis. Prentice Wall.Inc. Englewood Chiefs. New Jersey, USA. *Journal of Ecology, 63*, 995-1001.
Jukanti, A. K., Gaur, P. M., Gowda, C. L. L. and Chibbar, R. N. (2012). Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.): A review. *Br. J. Nutr., 108*(Suppl. 1), S11–S26.
Adhyaya, H. D., Bajaj, D., Narnoliya, L., Das, S., Kumar, V. and Gowda, C. L. L. (2016). Genome-wide scans for delineation of candidate genes regulating seed-protein content in chickpea. *Front. Plant Sci.*, *7,* 1-13.
Knights, E. J. and Hobson, K. B. (2016). "Chickpea overview," in *Reference Module in Food Science* (2nd *Edn*. *Vol*. 1) (Elsevier Ltd.).
Kumar, T., Hamwieh, A., Swain, N. and Sarker, A. (2021). Identification and morphological characterization of promising Kabuli chickpea genotypes for the short-season environment in central India. *Journal of Genetics, 100,* 33-42.
Lammerts, E. T., Struik, P. C. and Jacobsen, E. (2002). Ecological concepts in organic farming and their consequences for an organic crop ideotype. *Netherlands Journal of Agricultural Science, 50*, 1-26.
Mallikarjuna, B. P., Samineni, S., Thudi, M., Sajja S. B., Khan, A. W., Patil, A., Viswanatha, K. P., Varshney, R. K. and Gaur, P. M. (2017). Molecular mapping of flowering time major genes and QTLs in Chickpea (*Cicer arietinum* L.). *Front Plant Sci., 8*, 11-40.
Olsen, S. R., Cole, C. V., Watanabe, F. S. and Dean, L. A. (1954). Estimation of available phosphorus in soil by extraction of sodium bicarbonate. *USDA Circular, 930*, 19-23.
Orrell, P. and Bennett, A. E. (2013). How can we exploit above-belowground interactions to assist in addressing the challenges of food security. *Front. Plant Sci.*, *4*, 432-445.
Padmavathi, P., Murthy, S. S., Rao, V. S. and Ahamed, M. L. (2013). Correlation and path analysis in Kabuli chickpea (*Cicer arietinum* L.). *International Journal of Applied Biology and Pharmaceutical Technology, 4*, 107-110.
Panse, V. G. and Sukhatme, P. V. (1987). Statistical methods for agricultural workers. *Indian Council of Agricultural Research*, New Delhi p 359
Postgate, J. R. (1972). The acetylene reduction test for nitrogen fixation. Inc.p 343-356
Priyadarsini, L., Singh, P. K., Chatterjee, C., Sadhukhan, R. and Biswas, T. (2017). Estimation of Genetic Variability of Nodulation Characters and their Association with Different Agromorphic Characters and Yield in Chickpea (*Cicer arietinum* L.). *International Journal of Agronomy and Agricultural Research, 6*, 1928-1935.
Raju, A. C. and Lal, G. M. (2021). Correlation and path Coefficient analysis for quantitative traits in chickpea (*Cicer arietinum* L.). *International journal of botany and research, 11,* 15-22.
Raval, L. J. and Dobariya, K. L. (2003). Yield components in the improvement of chickpea *(Cicer arietinum* L.). *Annals of Agricultural Research, 24*, 789-794.
Roberfroid, M., Gibson, G.R., Hoyles, L., McCartney, A.L., Rastall, R. and Rowland, I. (2009). Prebiotic effects: metabolic and health benefits. *Br. J. Nutr*., *101*, 1–63.
Shafique, M.S., Ahsan, M., Mehmood, Z., Abdullah, M., Shakoor, A. and Ahmad, M. I. (2016). Genetic variability and interrelationship of various agronomic traits using correlation and path analysis in Chickpea (*Cicer arietinum* L.). *Academia Journal of Agricultural Research, 4,* 82-85.
Singh, K. B., Omar, M., Saxena, M. C. and Johansen, C. (1997). Screening for drought resistance in spring chickpea in the Mediterranean region. *Journal of Agronomy and Crop Sciences, 179,* 22-25.
Sood, V. K. and Sood, O. P. (2001). Effect of cropping system on some genetic parameters in soybean (*Glycine max* (L.) Merrill). *Indian Journal of Plant Breeding and Genetics*, *61*, 132-135.
Subhiah, B. W. and Asija, G. L. (1956). A rapid procedure for the estimation of available nitrogen in soils. *Current Science*, *25*, 259-260.
Tagore, G. S., Namdeo, S. L., Sharma, S. K. and Kumar, N. (2013). Effect of rhizobium and phoshphate solubilizing bacterial inoculants on symbiotic traits, nodule leghemoglobin and yield of chickpea genotypes. *International Journal of Agronomy*, 1-8.
Vekariya, D. H., Pithia, M. S., Mehta, D. R. and Dhameliya, H. R. (2008). Genetic variability, heritability, and genetic advance for seed yield and its components in F_2 generation of chickpea. *Natal Journal of Plant Improvement, 10,* 40-42.
Walkley, A. and Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Science, 37*, 29-38.

How to cite this article: Jeevanjot Kaur, Neelam Bhardwaj and Sunidhi Tiwari (2023). Differential Response of Chickpea (*Cicer arietinum* L.) Genotypes under Organic and Inorganic Input Conditions. *Biological Forum – An International Journal, 15*(10): 436-446.