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Improvement in Growth and Yield Attributes of Chickpea (CICER ARIETINUM L. CV. BG-256) By Interactive Effect of Thermal Powerplant Wastewater and Fly Ash Under Different Nitrogen Levels

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Abstract:— **The use of thermal power plant wastewater (TPPW) and coal fly ash in agriculture for irrigation need specific studies to evaluate their effect on different soils, crops and agro-climatic conditions. This study was therefore conducted to observe the suitability of wastewater for irrigation, and Cicer arietinum L.cv. BG-256was used as a test crop. The experiment was conducted in the winter season of 2000–2001 to evaluate its effect together with the basal application of four doses of nitrogen (N0, N10, N20, N30 kg ha−1). Fly ash (@ 10%) selected from previous study, conducted in the year 1999 was amended with soil to make the final weight 7 Kg ha-1. Wastewater irrigation resulted in the increased growth and yield of the crop. Lower fertilizer dose of nitrogen @ 10 Kg ha−1 together with wastewaterirrigation and fly ash amended soil (FA10) proved optimum, resulting in greater leaf area, plant fresh weight, dry matter (DM) and leaf NPK content, number of pods per plant, 100 seed weight and protein content relative to control which is found to be at par with higher N doses (N20 and N30). Thus fertilizer rates could be lowered without reducing yields when using wastewater for irrigation and fly ash (FA10) as an amendment to the soil.**

Key words: **Thermal power plant wastewater, fly ash, yield, chickpea, nitrogen.**

I. INTRODUCTION

In most parts of the developing world, fresh water supply is becoming increasingly limited due to overconsumption by the fast growing population of thesecountries. More than 60% of the valuable water usedeach year is diverted for irrigating crops. For Asia,which has two third of the world's irrigated land,the figure is still higher (85%) due to unscientific irrigation. The colossal wastage of our scarce freshwater resources can be reduced by various ways, important being the reuse of wastewater in agriculturewhich is gaining importance nowadays because ofits value as a potential irrigation source and a nutrient supplier. In addition to the manorial ingredients,it effectively augments the supply of water, the mostimportant requirement of cultivated crops.Wastewater not only offers an alternative water irrigation source, but also the opportunity to recycle plant nutrients (1). Its application might ensure the transfer of fertilizing elements, such as nitrogen (N), phosphorous (P), potassium (K+), organic matter, and meso and micro-nutrients, into agricultural soil and has been reported to increase crop yield (2, 3,4, 5, 6,7, 8 &9). Hence, wastewater nutrients can contribute to crop growth(10).Wastewater rich in organic materials and plant nutrients is finding agricultural use as a cheap way of disposal(11). Application of wastewater e. g. thermal power plant wastewater (TPPW) to cropland is an attractive option for disposal because it can improve physical properties and nutrient contents of soils (12). Thus, its use would help in water conservation recycling nutrients (NPK) in wastewater, reducing direct fertilizer inputs and minimizing pollution loads to receiving water bodies (13, 14 & 15).

Similarly, Disposal of high amount of fly-ash from thermal power plants absorbs huge amount of water, energy and land area by ash ponds. In order to meet the growing energy demand, various environmental, economic and social problems associated with the disposal of fly-ash would continue to increase.Every year thermal power plants in India produce more than 100 million tonnes of fly ash, which is expected to reach 175 millions in the near future (16). Disposal of this huge quantity of fly ash is posing a great problem due to its limited utilization in the manufacturing of bricks, cements, ceiling and other civil construction activities. This would further bring changes in land-use patterns and contribute to land, water and atmospheric degradation, if proper management options for handling ash are not undertaken (17, 18 & 19). Therefore, fly-ash management would remain a great concern of the century. Fly-ash has great potentiality in agriculture due to its efficacy in modification of soil health and crop performance. The high concentration of elements (K, Na, Zn, Ca, Mg and Fe) in fly-ash increases the yield of many agricultural crops. But compared to other sectors, the use of fly-ash in agriculture is limited.

While, the most important role of N in the plant is its presence in the structure of protein and nucleic acids which are the most important building and information substances of every cell. In addition, N is also found in chlorophyll that enables the plant to transfer energy from sunlight by photosynthesis. Thus, the supplies of N to the plant will influence the amount of protein, amino acids, protoplasm and chlorophyll formed. Consequently, it influences cell size, leaf area and photosynthetic activity (20,21, 22, 23 &24). Therefore, adequate supply of N is necessary to achieve high yield potential in crops. In general, N deficiency causes a reduction in growth rate, general chlorosis, often accompanied by early senescence of older leaves, and reduced yield (23 & 25).

Pulses, being an integral part of vegetarian diet in the Indian sub-continent, are a known rich source of protein. However, it must be admitted that the area under their cultivation has not increased in proportion to population explosion. Consequently the per capita availability of pulses has progressively declined from 60.7g day 1 in 1951 to nearly 36g in 2000 against the FAO/WHO recommendation of 80g (26). Chickpea (Cicer arietinum L.), an important pulse crop grown throughout the country, accounts for more than a third of the area under pulses and about 40% of their production in India, the average annual area and production being about 7-8 million hectares and about 4-5 million tonnes respectively (27).

Keeping in mind the importance of nitrogen (N), disposal problem of thermal power plant wastewater and fly ash, that can be used as nutrients for betterment of plant, and to minimize the use of chemical fertilizer, an experiment was conducted in the year 2000 at Department of Botany, Aligarh Muslim University, Aligarh on chickpea.

II. MATERIALS AND METHODS:

An experiment was conducted during the rabi (winter) season of year 2000 on chickpea cultivar BG 256, to strengthen the findings of earlier experiment (1999) with inorganic fertilizer doses. Here again the comparative effect of TPPW and GW was studied. On the basis of observations made during 1999, the best concentration of fly ash i.e. 10% was selected and added to the soil, making the final weight of fly ash amended soil up to 7kg ha 1. Different doses of nitrogen i.e. 0, 10, 20 and 30kg ha 1 were supplemented in order to work out the optimum dose for cultivar BG-256. A uniform basal dose of phosphorus and potassium at the rate of 20kg ha 1 each was also applied before sowing. Healthy seeds of more or less uniform size were surface sterilized and then inoculated (28). Seeds were procured from Indian Agricultural Research Institute (IARI), New Delhi and viable Rhizobium culture (Rhizobium sp.) specific for chickpea was also obtained from IARI, New Delhi. Before irrigation the water samples were collected and analysed for physico-chemical characteristics adopting the procedures outlined in the standard methods (29). The soil/flyash samples were collected before the start of the experiment. These samples were also analysed for standard physico-chemical properties according to some workers (30, 31, 32, 33, 34, 35 & 36). For investigating the comparative effect of TPPW, GW and fly ash under inoculated conditions, observations were carried out at vegetative, flowering, fruiting and at harvest stages. For the study of the root, the plants were uprooted carefully and washed gently to clear all the adhering particles. For assessing dry weight, three plants form each treatment were dried, after taking their fresh weight, in hot air oven at 80ºC for two days and weighed. The area of leaves was measured using leaf area meter (LA 211, Systronics, India). For nodule number, whole plant was uprooted with the precaution that the roots or the nodules may not be damaged. Samples were washed gently to wipe away all the adhering foreign particles and the number was carefully counted.

NRA and chlorophyll were estimated (37 &38). Healthy leaves were collected at different samplings stages for the estimation of N, P and K contents (39 &40).

Potassium was estimated with the help of flame photometer. Ten millilitres of aliquot was taken and K was read using the filter for potassium. A blank was also run side by side with each set of determinations. The readings were compared with a calibration curve plotted against known dilutions of standard potassium chloride solution. At harvest, yield attributes including seeds per pod, pods per plant, 100-seed weight, and seed yield per plant were noted and protein content (41) in the seeds was measured. The data for the growth and yield of each experiment were analysed statistically taking into consideration the variables (42). The 'F' test was applied to assess the significance of data at 5% level of probability ($p \leq 0.05$). The error due to replication was also determined.

Table 1. Chemical characteristics of soil and fly ash before sowing. All determinations in mg l-1 in 1: 5 (soil-water extract) or as specified.

Soil		Fly ash	
Determinations	Year 2000	Determinations	Year 2000
Texture	Sandy loam	CEC (meq 100g^{-1} fly ash)	7.34
CEC (meq 100g^{-1} soil)	2.88	pH	8.90
pH	8.30	Organic carbon (%)	2.19
Organic carbon (%)	0.789	EC (µ mhos cm^{-1})	1037.00
EC (µ mhos cm^{-1})	281.00	NO_3^-–N (g kg^{-1} fly ash)	–
NO_3^-–N (g kg^{-1} soil)	0.243	Phosphorus (g kg^{-1} fly ash)	2.22
Phosphorus (g kg^{-1} soil)	0.120	Potassium	11.00
Potassium	21.00	Calcium	19.03
Calcium	30.29	Magnesium	16.59
Magnesium	18.24	Sodium	14.27
Sodium	13.18	Carbonate	13.26
Carbonate	18.36	Bicarbonate	64.37
Bicarbonate	81.64	Sulphate	26.25
Sulphate	18.28	Chloride	19.11
Chloride	28.13		

Table 2. Chemical characteristics of ground water (GW) and thermal power plant wastewater (TPPW). All determinations in mg l 1 or as specified.

Determinations	2000			
	Sampling I		Sampling II	
	GW	WW	GW	WW
Ph	7.3	7.9	7.5	8.0
EC (µ mhos cm^{-1})	710	880	700	840
TS	902	1298	947	1288
TDS	520	637	528	621
TSS	404	658	431	694
BOD	16.17	68.10	17.35	69.24
COD	38.24	124.18	37.19	129.24
Mg	17.84	26.36	18.18	28.22
Ca	26.17	41.84	24.18	38.36
K	7.52	16.67	8.24	14.39
Na	17.13	44.29	15.38	41.37
HCO_3^-	67	93	69	92
CO_3	21	38	22	37
Cl^-	69.13	111.17	65.84	105.67
PO_4	0.70	1.22	0.74	1.34
NO_3–N	0.74	1.19	0.76	1.13
NH_3–N	2.19	5.31	2.10	5.12
SO_4	46	65	47	64

III. RESULTS AND DISCUSSION

In this factorial randomized pot experiment, the comparative effect of two irrigation water sources and three basal levels of nitrogen, supplemented with phosphorus and potassium at the rate of 20kg ha 1each applied uniformly before sowing, was studied on chickpea (*Cicer arietinum* L.) cv. BG 256. The growth characteristics and physiological parameters were recorded at three stages. Yield attributes including seed yield and seed protein content were recorded at harvest. TPPW proved efficacious for all the growth parameters studied, while GW gave significantly lowest value at vegetative, flowering and fruiting stages respectively. Among various nitrogen treatments (N0, N10, N20 and N30), N10 proved optimum for all growth parameters studied, being at par with N20; followed by higher dose of nitrogen i.e. N30 which gave at par values at all the sampling stages. Nitrogen treatment of 10kg ha 1 proved optimum when interacted with TPPW as well as GW. TPPW nitrogen combination gave better results than GW nitrogen combinations, whereas lowest values were recorded by GW×N0.¬The wastewater was enriched with considerableamount of nutrients which are considered essential for maintaining soil fertility and enhancing plant growth and productivity. Among them, nitrogen (N) is the most important element limiting plant growth. It is invariably required in large quantities and in wastewater it was present in both ionic forms (Table 2) and thus deserves special consideration. As vegetative growth includes formation of new leaves, stem and roots, the involvement of N through protein metabolism controls them. This was also clearly evident from the enhanced growth under the wastewater irrigation (Fig. 1, 2 and 3). Suitability of ammonium (NH4+–N and NO3-–N) ions for the growth and development of plants depends upon many factors (43). However, normally the highest growth rate and plant yield (Fig. 7b) are obtained by a combined supply of both; therefore, in the present study, the enhancement in growth could be due to cumulative effect of ammonium as well as nitrate ions together(44). It is noteworthy that applied ammonium nitrogen (NH4+–N) is toxic for some higher plants (45). However, in the presence of nitrate-nitrogen (NO3-–N), it has been reported to benefit wheat (Triticum aestivum) (46) and chickpea (47). Thus the observed nutritional superiority of wastewater for growth of chickpea was not exceptional and possibly explains better performance of crop growth under wastewater irrigation (Fig. 1, 2 and 3). A substantial increase in dry matter of test plants was also observed (Fig. 1, 3 and 4) because of the increased leaf area and expansion (Fig. 2) which might have influenced the light absorption within plant causingstimulation of PN, thereby optimizing the CO2 assimilation and photosynthetic production (48). The increase in leaf area brought about by the N supply causing expansion of individual leaves has also been reported by Taylor et al. (49) and Gastal and Lemaire (50). The possible reason for this may be through its effect on cell division and cell expansion (51). Another essential nutrient, P when it is supplied in limited amounts to sugar beet (Beta vulgaris); it has much greater impact on growth than on photosynthesis (52 &53). During the present study better growth of plants was observed receiving wastewater having phosphorus (Table 2) in addition to other nutrients, and it was also comparatively richer than ground water. The observation of improved performance of the crop receiving wastewater was therefore understandable. But, a regular supply of the enriched wastewater up to harvest ensured availability of P and thus improved the growth and which ultimately led to higher seed productivity. Next to N and P, K is the third most important macronutrient required in the largest amounts by the plant. It is known to play a significant role in stomatal opening and closing (54) and under light conditions the guard cells produce abundant adenosine triphosphate (ATP) in photosynthetic phosphorylation, thus supporting active K+ uptake with sufficient energy (55), and the resulting high-turgor pressure thus causes the opening of the stomata. The diffusion of carbon dioxide (CO2) into the stomata is followed by its transport into the chloroplasts where it is reduced by ribulose-1, 5-biphosphate carboxylase/oxygenase (RuBPCO). It is this supply of CO2 which catalyzes reversible dehydration of bicarbonate (HCO-3) to CO2 in close proximity to the CO2-fixing enzyme (48). It is also well known that N is fully utilized for crop production only when K+ is adequate (56) and the presence of K+ in wastewater was nearly double the amount present in groundwater (Table 2). Therefore, the crop under study was benefitted not only due its own physiological role (57) but also by enhancing the effect of N. This was also strengthened by the presence of higher N, P and K contents in the leaves of the plants receiving the wastewater (Fig. 6). In addition to these three major macronutrients explained above, the presence of other essential nutrients like sulphur (S) could have also played a vital role in plant metabolism (58). It may be pointed out that the application of N in the form of urea is ineffective unless S is applied simultaneously, and its deficiency reduces the leaf area (59) besides decreasing the chlorophyll contents (60). Moreover, in S-deficient plants not only does the protein content decrease but also the S content in proteins, indicating that proteins with lower proportions of methionine and cysteine but higher proportions of other amino acids such as arginine and aspartate are synthesized(48). This decrease in the S-rich proteins is not confined to wheat grains but can also be found in other cereals and legumes (61), and the lower S content of the proteins influences the nutritional quality considerably (62). In the present study the total protein was significantly enhanced in the wastewater-fed plants (Fig. 7c). Similarly, the presence of calcium (Ca2+) and magnesium (Mg2+) ions (Table 2) could have further added benefits, as Ca2+, being an essential component of the cell wall, is involved in cell division (63) while Mg2+ is a central atom of chlorophyll and is required for structural integrity of the chloroplast (64) on which the rate of photosynthesis is directly dependent. It may be pointed out that the chlorophyll content was enhanced in plants grown under wastewater (Fig. 5 and Table 2) indicating the possible involvement of Mg2+ in addition to other nutrients. The observed enhanced growth ultimately led to increase in 100-seed weight (Fig. 7a). Ensured supply and availability of the abovementioned nutrients might have played a cumulative role in enhancing the metabolic activities and finally the seed yield and protein (Fig. 7b&c).

Fly ash (FA10) when applied with nitrogen (N10) gave better results being at par with FA10N20 and

FA10N30 as compared to FA10N0 for all growth, physiological and yield parameters. FA amendment increases the porosity and water-holding capacity, due to the fine-textured nature of fly ash, which helps in improving the physical health of the soil for supplying all essential nutrients in significant quantities for plant growth. The addition of fly ash into soil increased the organic carbon content which helps in binding soil particles in aggregates and improving the water-holding capacity of soil. Such improvement in agronomic properties of soil by constituents of fly ash has also been reported elsewhere as well at Aligarh (65,66, 67& 68).

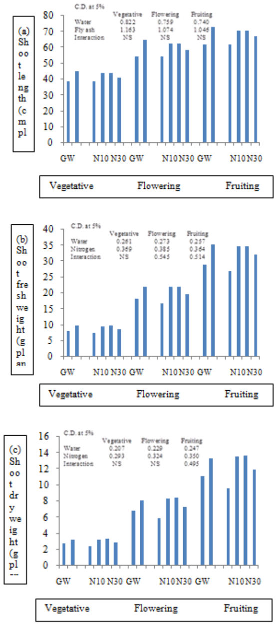
Plant growth is the expression of interplay between meristematic activities and metabolic processes leading to an increase in biomass 64). In addition to the role of N in cell division and expansion (69), it is also essential for a number of biologically important molecules. Therefore, the requirement of N (and the other essential nutrients) during the vegetative growth of a plant is determined primarily by the rate of CO2 assimilation and if it is high, the required nutrients must be correspondingly at optimum levels in order to convert the photosynthates efficiently into other metabolites.

Thus, growth and yield parameters were noted to be significantly affected by N application (N10 proving optimum) as a result of the cumulative enhancement of growth and yield parameters, including seed yield (Figs. 1-7). This dose was also found to be optimum for leaf area, NRA and chlorophyll content (Figs. 2&5) which finally led to more pods and the heavier seeds (Fig. 7b). By contrast application of excess N (N30) resulted in decreased grain yield and proved deleterious. Toxicity due to N, when applied as urea is known to appear at two stages of plant growth. The first at seedling stage may be due to accumulation of NH4+ (after hydrolysis of urea) which becomes toxic at pH 8 and above. The second is due to accumulation of NO2 under certain conditions damages young plants (70). Contrary to above findings, higher optimum doses up to 30 kg N ha 1 were reported for chickpea by Sharma et al. (71) and Krishna et al. (72). It was not surprising that in our study comparatively lower dose (N10) proved effective as the applied wastewater had sufficient N in the form of NH4+ and NO3 ions. In case of legumes due to rhizobial activities, host plants grow well in soil even with low N doses and no benefit from this association may occur if high levels of fertilizer N are given (73). This was in conformity with the present observations. Since N10 and N20 were at par in their effect therefore it may be concluded that N20 led to luxury consumption, thereby proving wasteful, while N30 affected adversely thereby proved toxic when wastewater was the source of irrigation, which proved economically as well as environmentally viable.

When nodulation was considered similar observations were made. The beneficial effect of lower dose (N10) was noted to increased root formation (Fig. 3). This provided more surface area for bacterial infection. However, application of N beyond a certain level is known to delay and even suppress nodulation (74, 75, 76, 77 &78). On the other hand, the crop grown without nitrogen (N0) expectedly gave significant lowest values as some starter dose of N is always needed even by the leguminous plants to grow normally. Nitrate reductase levels have been shown to fluctuate in response to changes in environmental conditions, including availability of N (79 & 80). Enzymes are sensitive to nutrient levels as is indicated in the present study where NRA was found to decrease with comparatively higher N dose (Fig. 5a). Similar observation has been made in trifoliate leaves in Phaseolus lunatus at different canopy positions by Wallace (81) and Andrews et al. (82). The induction of NRA requires very low concentration of nitrate suggesting that nitrate is actually sensed more as a hormone than as a nutrient (83). Nitrogen also increased the leaf chlorophyll and NPK contents as it increased the availability of substrate for protein synthesis allowing the development of more and larger chloroplasts with extensive thylakoid system and larger stomal volume (84). The increase in leaf NPK (Fig. 6) was due to the synergistic interplay of the three nutrients, which are known to accelerate root proliferation, thus, extracting more nutrients present in the root zone leading to development of larger canopies (Fig. 2) and greater dry matter accumulation (Figs. 1&2). Similar positive interactions between N and P were also noted by Russell (85) and between N and K by Murphy (86). N as an essential macronutrient has the distinction of being absorbed both as cation as well as an anion. This puts N in a unique relationship of both an anion-cation as well as cation-cation interaction.

Expectedly the application of N enhanced seed protein contents (Fig. 7c) as it chief constituents of proteins. Its adequate supply can increase the amino acid levels through the conversion of organic acids produced from carbohydrates during respiration. As pointed out by Pretty (87), some quality factors in a few grasses were related to the effective utilization of N and the conversion of N-compounds into true proteins. Improvement in seed protein content was also boosted due to the addition of K, applied uniformity as the starter dose alongwith N, as K influences the level of some non-protein N components and positive role in converting these proteins. The N effect on seed protein was also dependent upon the type of crop, its cultivars and other environmental factors including water. Smika and Greb (88) observed the relationship of soil NO3-–N and soil water for the protein in wheat. The former was positively correlated with grain protein where opposite relationship was noted due to available soil water. In their opinion adequate soil moisture in addition to N was the important factors for this parameter. Since, the present work was carried but in pots and water was given regularly, therefore, possible protein in the present study was increased.

Finally it was concluded that Plants irrigated with TPPW performed better when supplemented with low fertilizer N level, N10, thus proving the utility of wastewater in saving some amount of costly nitrogenous fertilizers which simultaneously solving the problem of its disposal partially. N30 proved deleterious, while N20 showed luxury consumption when given with wastewater. Nodulation and seed protein content were also increased by the application of N10, while N30 decreased nodulation.



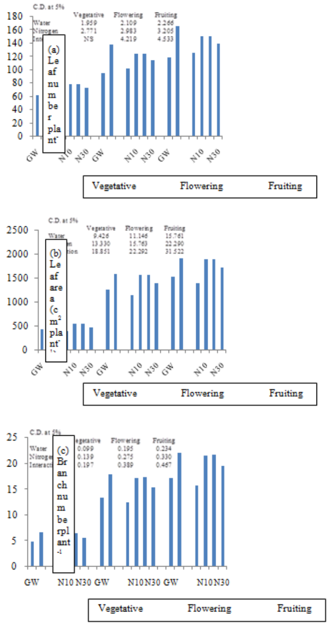
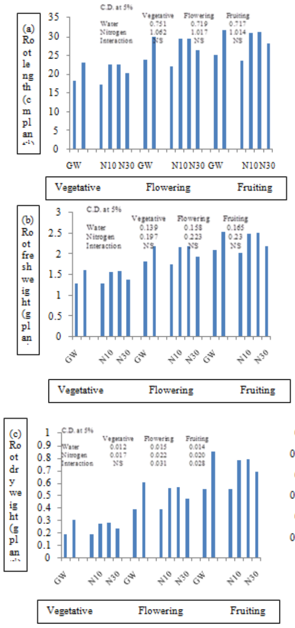


Fig. 1. Effect of wastewater and nitrogen on chickpea cv. BG-256 Fig. 2. Effect of wastewater and nitrogen on chickpea cv. BG-256



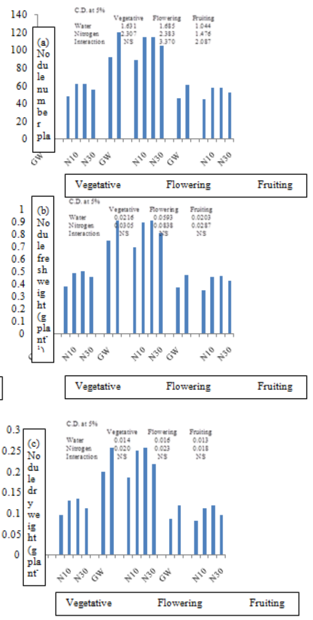


Fig. 3. Effect of wastewater and nitrogen on chickpea cv. BG-256 Fig. 4. Effect of wastewater and nitrogen on chickpea cv. BG-256

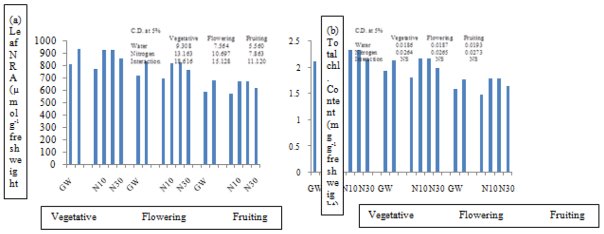
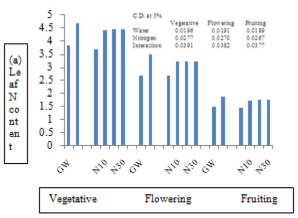
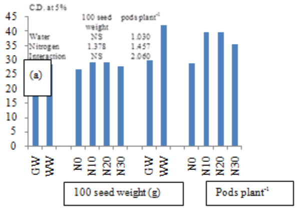
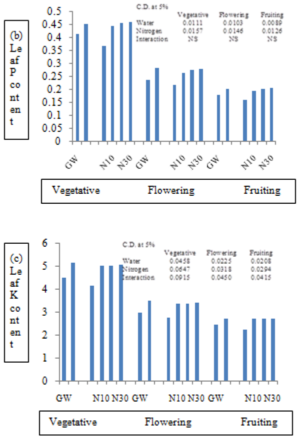


Fig. 5. Effect of wastewater and nitrogen on chickpea cv. BG-256







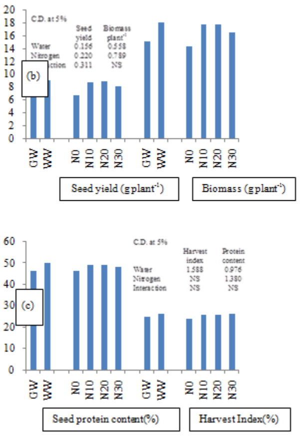


Fig. 6. Effect of wastewater and nitrogen on chickpea cv. BG-256 Fig. 7. Effect of wastewater and nitrogen on chickpea cv. BG-256

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