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PROMOTION OF BIOMASS, PHOTOSYNTHETIC RATE, YIELD AND QUALITY CHARACTERISTICS OF CHILLI (*CAPCICUM ANNUUM* L.) BY INTERACTIVE EFFECT OF NITROGENOUS FERTILIZERS AND WASTEWATER

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Abstract

In recent years water shortages and environmental hazards of wastewater have promoted the farmers to use of wastewater for irrigation especially for the cultivation of vegetable crops in urban areas. This study was therefore conducted to observe the promotion of biomass, photosynthetic rate, yield and quality of Chilli (*Capsicum annuum* L.) by interactive effect of nitrogenous fertilizer and wastewater. Four different doses of nitrogen at the rate of 0, 30, 60 and 90 kg N/ha along with a constant dose of phosphorus at the rate of 60 kg P/ha and potassium at the rate of 50 kg K/ha were applied one day prior to sowing. Seedlings were irrigated with three levels of waters (GW, 50%WW and 100%WW). The data were recorded at 60 (DAS) while yield and quality characteristics were determined at harvest. Results revealed that wastewater irrigation resulted significant increase in shoot and root length, fresh and dry weight of shoot, leaf number and area, total chlorophyll content and net photosynthetic rate (P_N). Fruit length, number and fresh yield were recorded at harvest while ascorbic acid was tested in green chillies. Among nitrogen treatments, N_{60} proved best for most of the characteristics while among interactions the lower nitrogen dose N_{30} with 100%WW proved optimum by giving at par result with combination of higher nitrogen treatment N_{60} with GW indicating that fertilizer rates could be lowered with the use of wastewater which can serve not only as the source of water but of nutrients also. However, regular monitoring of wastewater and soil for any build up of heavy metals is necessary. The physical and chemical parameters of wastewater were also tested and most of them were found to be well within the permissible limits as set by the Food and Agriculture Organization (FAO).

Key words: Ascorbic acid, Photosynthetic rate, Yield, Nitrogen, Wastewater.

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INTRODUCTION

Food is the most basic of all human needs, so agriculture in broadest sense will remain the most important human activity. It may be significant to note that land use for agriculture stands at about 11% of the total land area and about 26% for permanent pasture [41]. The productivity of a crop depends upon several factors in which water and plant nutrients, among other inputs, are the two most important factors for normal growth of any crop. However, it must be admitted that excessive use of inorganic fertilizers is an important source of soil and water pollution as nutrients through runoff water goes to nearby water bodies or leached through the soil beyond the root zone eventually reaching the groundwater and sometimes their long term presence in soil also may lead to acidification thus exploitative food production offers great dangers if carried out with only an immediate profit or production objective. The big challenge faced by global community is how to reconcile global food production with growing demands and shrinking resources within the limits of acceptable degradation of natural resources. Of the total water found on the earth only about 0.4% fresh water available for plants, animals and human beings [8]. In recent years water is becoming an increasingly scarce resource and this has forced scientists to consider alternate source of water which might be used economically and effectively. Thus depletion of freshwater reserves at a faster rate, coupled with the problem of water pollution promoted the development of wastewater reuse in irrigation especially for the cultivation of vegetable crops in urban areas. Use of wastewater as a source of irrigation not only solves its disposal problem but also serve as a source of plant nutrients and organic matter. However, wastewater may contain some undesirable constituents that may pose negative environmental effects and health risks. Thus there is urgent need for the wastewater management in a scientific manner and sufficient scope. Nutrient supply in general considered to be most important limiting factor for growth and productivity [24]. Most of the plants require seventeen essential elements including Ni which was added more recently [18] for their normal growth and development. Of these N, P and K are the three major macronutrient effective in promoting the crop yields and required in large quantity, thus the maintenance of an adequate supply of nutrients to crop is one of the most basic and vital requirements for sustained crop growth and productivity. Agro ecosystems exports large quantities of nutrients in crop biomass and therefore, require large inputs regardless of internal cycling [17]. Nitrogenous fertilizers are comparatively more misused inputs in agriculture and both under use and over use are wide spread. This indiscriminate use often leads to wastage and runoff causing pollution. Thus efficient use of fertilizers is essential for maintaining the soil quality, fertility and productivity. Use of inorganic and organic fertilizers has amused a great significance in recent years in vegetables production, for two reasons. Firstly, the need for continued increase production and per hectare yield of vegetables requires the increase amount of nutrients. Secondly, the results of a large number of experiments on inorganic and organic fertilizers conducted in several countries reveal that inorganic fertilizer alone cannot sustain the productivity of soils under highly intensive cropping systems [34]. Among nutrients nitrogen increases the yield of chilli [20] and potassium is reefed as quality element and known to improve colour and glossiness of chilli fruits. Thus the main objective was to minimize the use of inorganic fertilizers and optimize the utilization of nutrients present in the wastewater and also safeguard the pollution of water and soil by using it in crop cultivation.

MATERIALS AND METHODS

Wastewater includes wastewater from the households and sewage together with the wastewater from local industries of lock and electroplating as well and was collected from the outside of Aligarh city nearly 5 km from the town where it was being used by local formers to irrigate crops. The experiment was carried out in the naturally illuminated net house of the department of Botany, Aligarh Muslim University, Aligarh, and each treatment was set simultaneously in triplicate using a complete randomized block design with four different nitrogen treatments at the rate of 0, 30, 60 and 90 kg/ha being watered by tap water (GW) and wastewater (50%WW and 100%WW). A uniform basal dose of phosphorus at the rate of 60 kg ha^{-1} and potassium 50kg ha^{-1} were also applied along with different doses of K. The dilution of 50% wastewater was obtained by mixing the GW and WW in a 1:1 ratio. Many physio-chemical characteristics were analysed by adopting the procedures outlined in the standered methods [3] (Table 1) The soil for pot filling was collected from University Agriculture Farm and analysed for various physico-chemical properties [14] (Table 2). The plants were sampled at 60 DAS to make various observations. The plants were uprooted gently and washed under running tap water to remove adhering soil. The plant length and fresh mass of the whole plant were assessed. The samples were then dried in an oven at 80°C for 48h. The dehydrated samples were then weighed to recorded dry mass. Leaf area was measured using a portable leaf area meter (LA-21, Systronics, India). The method of [23] was used to calculate total chlorophyll content while net photosynthetic rate (P_N) was measured in uppermost fully expanded leaves on clear sunny days between 1100 and 1230 h, using a portable photosynthetic system (LICOR 6400, Lincoln, NE, USA). Ascorbic acid was calculated by adopting the method of [31]. At harvest, yield attributes including fruit length, fruit number and fruit fresh yield were measured.

Data analysis

The data recorded from the experiment were subjected to two-way analysis of variance (ANOVA) using the SPSS softwere package, and the mean were compared following the method given by [15]. An F test was applied to assess the significance of the data at 5% level of probability (P=0.05).

RESULT AND DISCUSSION

Wastewater obtained from urban source has a great potential for the reuse as a source of irrigation water and nutrient as well as a soil conditioning agent [7]. It contains considerable amount of nutrients essential for maintaining soil fertility and enhancing plant growth and yield. The analysis of wastewater has revealed that it had an average of EC, $_{P}H$, TS, TDS, and TSS, carbonate and bicarbonates which were within the permissible limits of FAO guidelines for irrigation water quality (Table1). The major effect of EC and TDS on crop productivity is the inability of the plants to compete with ions present in the soil for water while the chloride content was comparatively low and may not cause toxicity problems. The $_{P}H$ (7.5-8.2) of the wastewater was within the range important for nutrient availability because it is the indicator of acidity and basicity of water. It also has considerably higher BOD and COD then groundwater, that determines the pollution power or strength of wastewater in terms of oxygen that would required by micro-organism for their complete stabilization. Beneficial effects of wastewater on the physical, chemical and biological properties of soils were reported by several workers [31, 1, 6]. Wastewater was used not only as a substitute of chemical fertilizer but also as the soil conditioner that would increase soil fertility and crop productivity [19, 10]. Wastewater also increases the density of soil microorganisms including bacteria, fungi and actinomycetes that helps in nutrient availability of plants [25]. Concentrations of some essential inorganic ions were higher in wastewater than in groundwater. These could have played a beneficial role as these are essential for plants [16]. Among nutrients, nitrogen is the most important element, which is invariably required in large quantities and in wastewater it was present in both ionic forms (Table 1) and thus deserves special consideration. In addition mineral nutrients wastewater also contains some heavy metals, which were within permissible limit of FAO guideline. 100% WW produced 11.91% and 18.08% higher shoot length and root length respectively over GW, while 7.96% increase was recorded by 100%WW in shoot fresh weight over GW. Leaf number and leaf area gave an increase of 14.08% and 14.95% under 100%WW over GW respectively. This enhanced vegetative growth under wastewater irrigation was due to the presence of both ionic forms of nitrogen in wastewater. Nitrogen control vegetative growth of plants through their involvement in protein metabolism. Wastewater contains considerable high amount of ammonium (NH_4^+) or nitrate (NO_3^-), which are the sole source of nitrogen supply and most important for better growth and yield of crop plants [21] because it involves in cell division and elongation and it is also an important structural constituent of many important metabolites, amino acid and protein. Generally the highest growth and yield are obtained by the combined supply of both ions, but it may be noted that the form of N plays a key role in the cations-anion relationship in plants as about 70% of cations and anions taken up are represented by either NH_4^+ or NO_3^- [38]. Since N is the main constituent of all amino acids in proteins and lipids that act as structural compound of chloroplasts [4] thus presence of N in both wastewaters well as in the form of inorganic fertilizers might have increased number of meristematic cells and growth leading to the formation of branches in addition to leaf expansion and number. This was evident from the 14.08 and 14.95% increase in leaf number and leaf area of the plants irrigated with 100% WW over GW. Thus the observed nutritional superiority of wastewater for growth of chilli was not exceptional and possibly explains better performance of crop under wastewater irrigation (Fig. 1) but earlier many other researchers observe its nutritional superiority for the cultivation of other vegetable and crop plants [2, 5, 36]. A substantial increase of 7.87% in shoot dry weight was also observed (Fig 1) because of the increased leaf area and expansion, that might stimulated the photosynthetic rate (P_N) by influencing the light absorption within plant. The increase in leaf area brought by the N supply causing expansion of individual leaves has also been reported by [37, 13] because N stimulated the cell division and cell expansion [22]. Likewise wastewater also recorded higher values for the physiological parameters. It recorded an increase of 13.66% and 13.93% in photosynthetic rate and chlorophyll content over GW. Increase in total chlorophyll content may be due to higher availability of Mg^{2+} in wastewater as Mg^{2+} is the central atom of chlorophyll molecule which is required for the structural integrity of chloroplasts [27] and quantitative estimation of chlorophyll may be considered as an index of primary productivity. Therefore, a regular supply of the enriched wastewater up to harvest ensured its availability and thus improved the growth, development and photosynthetic capacity (Fig 1, 2). Like growth and physiological parameters wastewater application recorded an increase of 3.27, 3.62 and 4.77% in fruit length at II, III and IV fruit pickings respectively over GW while wastewater recorded an increase of 13.10 and 10.20% increase in fruit number at I and II pickings respectively. Fruit yield recorded an increase of 16.16, 11.87, 17.52 and 11.81% under WW at I, II, III and IV pickings respectively (Table 3). This increase in yield under WW application may be explained on the basis of increase in leaf area by wastewater

application. Increased leaf area might have allowed plants to trap more radiant energy required for enhanced photosynthetic activity which in turn might have increased the yield.
After N, P is another essential nutrient that is a constituent of macromolecular structure, was also present in wastewater in form of phosphate. It has many roles in cell division, stimulation of early root growth, hastening plant maturity and fruiting and fruit yield. The beneficial effect of phosphorus on the leaf area has been reported by [29] in cowpea, [30] in groungnut and [36] in chickpea. During the present study better growth of plants was observed receiving wastewater having 1.130 mg/l (Table 1) in addition to other nutrients, and it was also comparatively richer than GW. It is important to note here that in short season crops like some vegetables, growth responses to applied P may persist up to harvest because P applied to the soil is very rapidly changed its less soluble form and therefore become less and less available with time [35]. K is the third most important macronutrient required in largest amount by the plants. It plays a significant role in stomatal opening and closing [11]. It is also well known that N is fully utilized for crop production only in presence of adequate K^+ [26] and the presence of K^+ in WW is much higher than the GW (Table 1). Thus the test crop was benefitted by not only its own physiological role [40] but also by the enhancing effect of N.

In addition to these three major macronutrients presence of some other essential nutrients like S, Ca^{2+}, Mg^{2+}, Cl^- and Na^+ also play a vital role in plant growth and development. S involve in plant metabolism and its deficiency is common [28]. Application of N in form of urea is ineffective unless S is applied simultaneously. S deficiency reduces the leaf area [39], which in turn decreased the chlorophyll content [9] and ultimately yield. Similarly presence of Ca^{2+} and Mg^{2+} ions in wastewater could further benefitted the test crop as Ca^{2+} being an essential component of the cell wall, is involved in cell division [33] while Mg^{2+} is the central atom of the chlorophylle, on which the rate of photosynthesis is directly dependent. The rate of photosynthesis is lower in Mg^{2+} deficient plants [12]. It was earlier mentioned that the chlorophyll content and photosynthetic rate was higher in plants irrigated with wastewater (Fig. 2). Cl^- is also one of the essential nutrient present in wastewater could played an important role in stomatal regulation while Na^+ is not essential and has been placed in the beneficial elements for plants, its presence may be stimulated the growth that is mainly caused by its effect on cell expansion and also on the water balance of plants. In the present experiment enhanced growth (Fig. 1), physiological (Fig. 2) and yield characteristics (Table. 3) under N_{60} were also observed, while wastewater with a comparatively lower nitrogen dose N_{30} proved beneficial. Better performance of chilli crop under higher nitrogen dose was explained on the basis of vital role of nitrogen in cell division, cell expansion and stimulation of various enzymes, which lead higher leaf area and number provide much surface area for photosynthesis and produce much more photosynthate that finally gave higher yield. Wastewater with lower nitrogen dose proved beneficial because wastewater contains additional both form ionic forms of nitrogen.

CONCLUSION

The results obtained from the pot experiment aimed to evaluating the use of wastewater for the cultivation of chilli especially near urban areas where it is easily and cheaply available. Four levels of nitrogen supplement were also applied for the comparison with the unfertilized treatments. The wastewater proved an effective source of essential nutrients and even it could not be supplemented the whole nutrient requirement of the crop but it can reduced the quantity of fertilizers because wastewater also a source of nutrients. Finally the wastewater irrigation in combination with lower nitrogen dose proved optimum and gave result statistically similar with GW along with higher nitrogen dose. Thus wastewater reuse as a source of irrigation water and nutrient can effectively fill the increasing gap between water demand and water availability up to some extent.

Table 1 Physico-chemical characteristics of groundwater (GW), 50% wastewter (50% WW) and 100% wastewater (100%WW). All determinations in mg l^{-1} or as specified.

Determinants	GW	50%WW	100%WW
Colour	Colourless	Lightly black	Dark black
Odour	Odourless	Slightly unpleasant	Unpleasant
p^H	7.3	7.5	7.9
Electrical conductivity (dS m^{-1})	0.75	0.92	1.42
Total solids	915	1220	1627
Total dissolved solids	549	786	1088
Total suspended solids	385	435	549
Biological oxygen demand	17.40	51.29	122.52
Chemical oxygen demand	55.22	92.65	152.44
Nitrate – nitrogen	0.73	2.12	3.17
Ammonium-nitrogen	0.10	0.58	0.99
Phosphate	0.24	0.92	1.13
Potassium	4.21	11.24	19.23
Calcium	22.52	42.33	59.48
Magnesium	22.12	75.16	138.56
Carbonates	49.48	103.9	138.44
Bicarbonate	59.56	78.23	89.24
Sulphate	35.28	40.57	82.18
chloride	57.45	95.45	120.45
Sodium	16.37	34.28	49.26

Table 2 Physico-chemical characteristics of soil collected before sowing. All determinations in mgl^{-1} in 1:5 (soil-water extract) or as specified.

Determinants	Soil
Texture	Sandy loam
Cation exchange capacity (CEC) (meq 100 g^{-1} soil)	2.54
p^H	7.40
Organic carbon (%)	0.429
Electrical conductivity (µ mhos cm^{-1})	245.00
NO^-_3-N(g kg^{-1} soil)	0.347
Phosphorus (g kg^{-1} soil)	0.115
Potassium	9.4
Calcium	24.36
Magnesium	16.59
Carbonate	20.33
Bicarbonate	105.46
Sodium	14.21
Sulphate	17.32

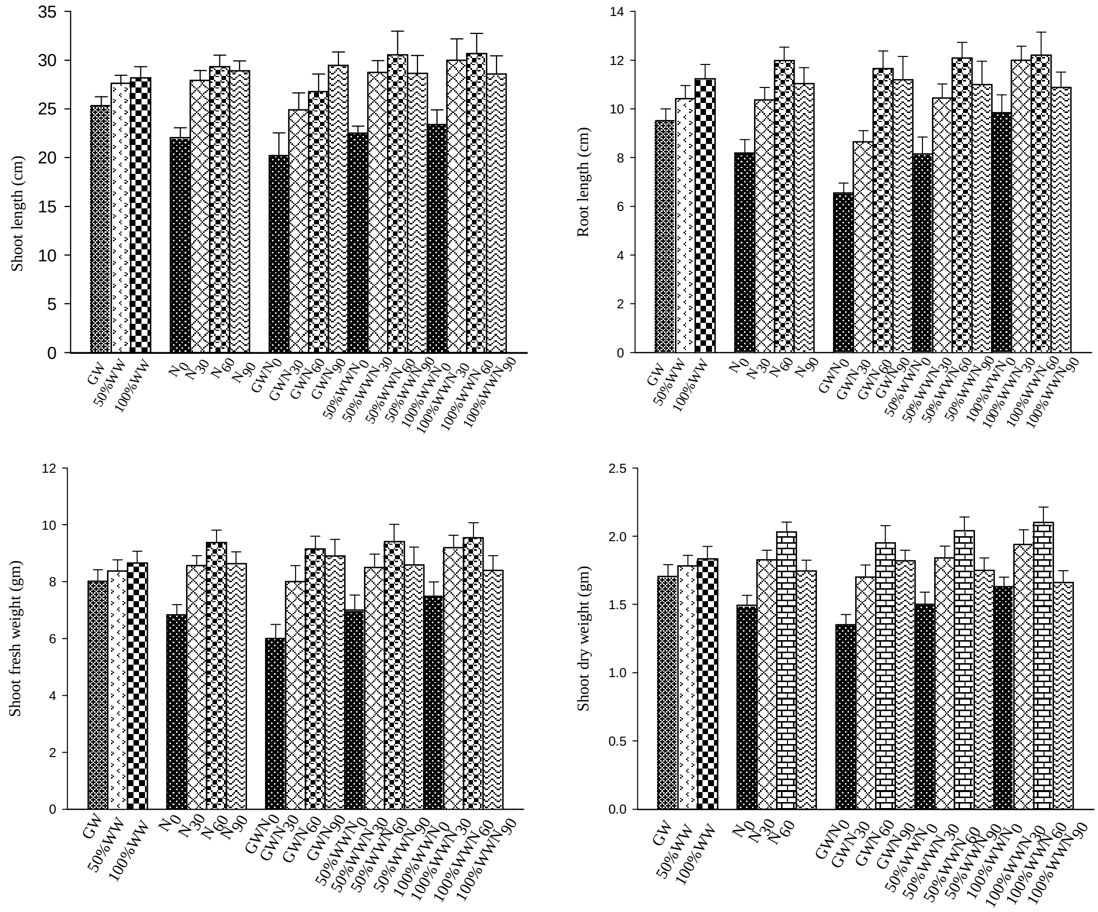

Figure 1. Effect of wastewater irrigation and different levels of nitrogen (N) on shoot length (cm), root length (cm), shoot fresh weight (gm) and shoot dry weight (gm) of chilli (*Capsicum annuum* L.) at 60 DAS. Values represent means of three replicates ± standard error (SE).

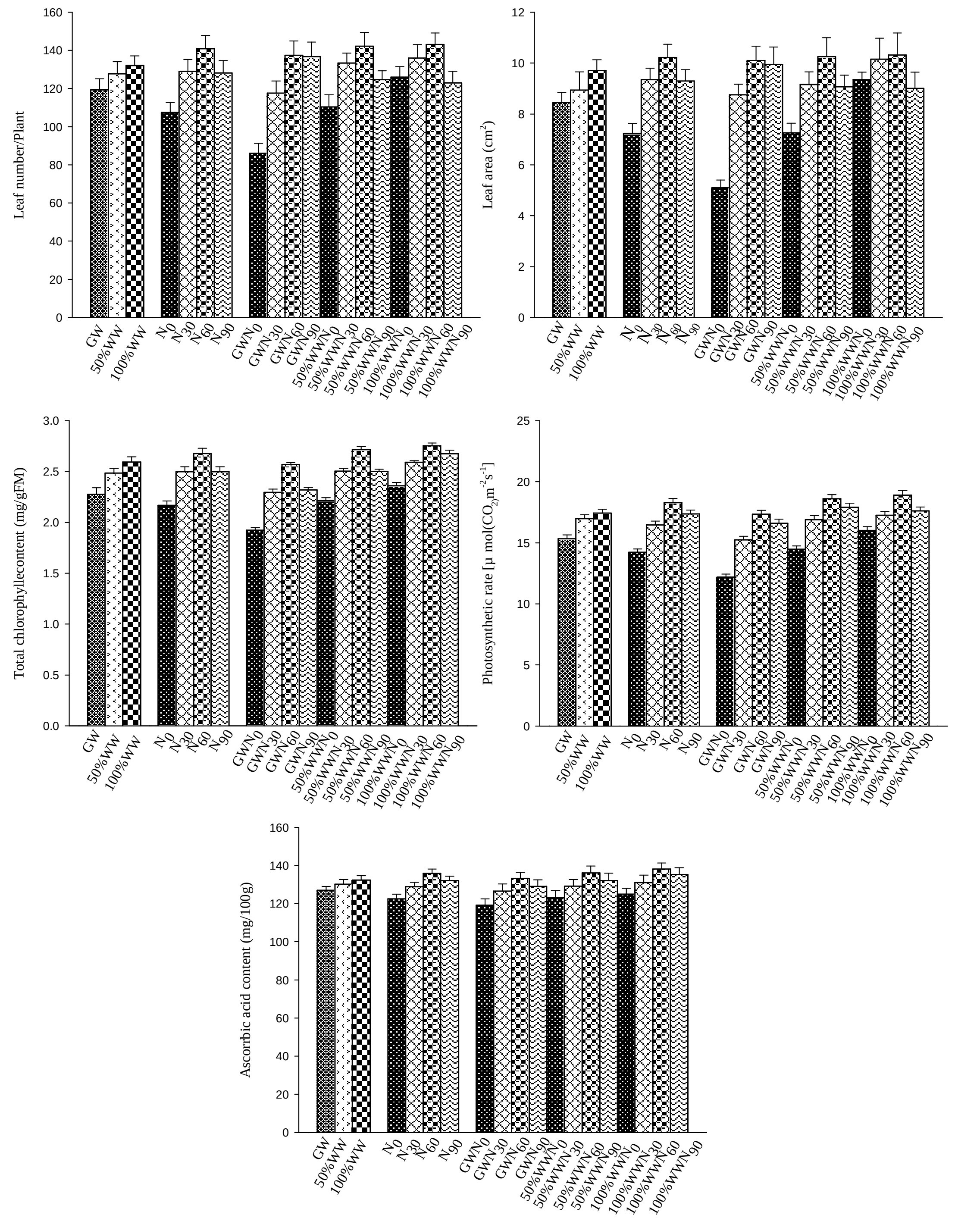

Figure 2. Effect of wastewater irrigation and different levels of nitrogen (N) on leaf area (cm2), leaf number/plant, chlorophyll content (mg/g FM), photosynthetic rate [µmol (CO_2) $m^{-2}s^{-1}$] and ascorbic acid content (mg $100g^{-1}$) of chilli (*Capsicum annuum* L.) at 60 DAS. Values represent means of three replicates ± standard error (SE).

Table 3 Yield parameters of *Capsicum annum* L. under the treatment of GW, 50%WW and100%WW along with different levels of N at four picking stages (P) of harvest.

TREATMENTS	Fruit length plant^{-1}				Fruit number plant^{-1}				Fruit yield plant^{-1}			
	P1	P2	P3	P4	P1	P2	P3	P4	P1	P2	P3	P4
GW	5.570	6.74	6.90	7.47	7.44	8.17	8.33	9.00	24.01	30.63	34.81	40.94
50%WW	5.912	6.75	7.08	7.63	8.17	8.75	8.75	9.33	26.57	33.08	38.26	44.38
100%WW	5.938	6.96	7.15	7.83	8.42	9.00	8.00	9.50	27.90	34.26	40.91	45.77
N_0	4.632	5.76	6.00	6.42	6.70	7.11	7.56	8.22	22.00	25.67	31.67	35.44
N_{30}	6.320	7.30	7.49	8.04	8.44	9.11	9.22	9.89	29.17	35.32	40.74	47.34
N_{60}	6.642	7.87	7.83	8.61	9.33	9.78	9.89	10.44	35.83	40.89	49.14	55.61
N_{90}	5.63	6.31	6.83	7.51	7.55	8.56	8.22	8.56	17.65	28.76	30.42	36.40
GWN_0	4.09	5.53	5.82	6.12	5.10	6.00	6.67	7.33	16.00	21.00	24.00	28.31
GWN_{30}	5.95	6.88	7.07	7.62	7.67	8.67	8.67	9.33	24.15	32.59	34.49	41.63
GWN_{60}	6.40	7.81	7.72	8.52	9.00	9.33	9.67	10.33	33.84	38.73	47.27	53.22
GWN_{90}	5.84	6.72	6.97	7.63	8.00	8.66	8.33	9.00	22.08	30.18	33.47	40.59
50%WWN_0	4.80	5.75	6.00	6.42	7.00	7.33	7.67	8.33	23.00	26.00	32.00	36.00
50%WWN_{30}	6.51	7.15	7.62	7.89	8.33	9.00	9.00	10.00	29.66	35.37	41.13	48.40
50%WWN_{60}	6.73	7.85	7.82	8.67	9.33	10.00	10.00	10.33	36.39	41.54	49.40	56.21
50%WWN_{90}	5.72	6.23	6.86	7.53	8.00	8.66	8.33	8.67	17.20	29.44	30.50	36.92
100%WWN_0	5.00	6.00	6.20	6.71	8.00	8.00	8.33	9.00	27.00	30.00	39.00	42.00
100%WWN_{30}	6.50	7.86	7.80	8.60	9.33	9.67	10.00	10.33	33.69	38.00	46.59	52.00
100%WWN_{60}	6.80	7.96	7.94	8.63	9.67	10.00	10.00	10.67	37.00	42.39	50.75	57.41
100%WWN_{90}	5.35	6.00	6.65	7.37	6.67	8.33	8.00	8.00	13.66	26.65	27.28	31.68
LSD at 5%												
Nitrogen (A)	0.4648	0.0858	0.1676	0.0735	0.6658	0.5721	0.5299	0.969	1.0653	0.7959	1.5830	1.6823
Water (B)	2.4232	0.0743	0.1451	0.0637	0.5766	0.4954	0.6119	0.857	0.9226	0.6893	1.3709	1.4569
A×B	0.8051	0.1486	0.2903	0.1273	1.1531	0.9909	1.0598	1.103	1.8452	1.3786	2.7418	2.9139

REFERENCES

1. Aggelides, S.M. and Londra, P.A., 2000, Biores. Techno. 71, 253–259.
2. Ahmad, K.H., Fawy, H.A. and Abdel-hady, E.S., 2010, Agriculture and Biology Journal of North America, 1, 1044-1049.
3. APHA 1998, Standard Methods for the Examination of Water and Wastewater, 20th Ed. American Public Health Association, Washington, D.C.
4. Arisha, H.M. and Bradishi, A., 1999, J. Agric. Res., 26, 391-405.
5. Begum, S.A., Alam, M.J., Rahman, S.S. and Rahman, M.M., 2010, Bangladesh J. Sci. Ind. Res., 45, 101-104.
6. Benitez, E., Romero, M., Gomez, M., Gallardolaro, F. and Nogales, R., 2001, Water Air Soil Pollut, 132, 75-87.
7. Cameron, K.C., Di, H.J., Anwar, M.R., Russell, M.J. and Barnett, J.W., 2003, New Zeal. J. Agr. Res., 46, 147-154.
8. Cunningham, W.P. and Saigo, B.W., 1995, *Environmental Science*: *A Global Concern*. 3rd Ed. WCB Publ., U.S.A.
9. Deitz K.J. 1989, Plant Physiol., 134, 551–557.
10. Erfani, A., Haghnia, A. and Alizadeh, A., 2002, J. Sci. Technol. Agric. Natu. Resour., 6, 71-90.
11. Fischer, R.A., 1968, Science, 160, 784–785.
12. Forster, H., 1980, Journal of plant nutrition and soil science, 143, 627–637.
13. Gastal, F. and Lemaire, G., 2002, J. Exp. Bot., 53, 789–799.

14. Ghosh, A.B., Bajaj, J.C., Hasan, R. and Singh, D. 1983, Soil and Water Testing Methods: A laboratory manual, Indian Agricultural Research Institute (IARI), New Delhi.
15. Gomez, K.A. and Gomez, A.A., 1984, Statistical procedure for Agricultural Research, Wiley, New York.
16. Gori, R., Ferrini, F., Nicese, F.P. and Lubello, C. 2000, J. Environ. Hortic, 18, 108-114.
17. Hendrix, P.F., Crossley, D.A., Blair, J.M. and Coleman, D.C., 1990, Soil biota as components of sustainable ecosystems. In: C.A. Edwards, R. Lal, P. Madden, R.H. Miller and G. Haise (eds.), Sustainable agricultural system, SWCS, Ankeny, USA, 637-654.
18. Hopkins, W.G. and Huner, N.P.A. 1995, Introduction of Plant Physiology, 4th Ed. Printed in the United State of America.
19. Jenkins, C.R., Papadopoulos, I. and Stylianou, Y., 1994, Pathogens and wastewater use of irrigation in Cyprus. In: Proceeding of Int. Conf. on Land and Water, Valenzano, Bari, Italy. 4-8 Sep.
20. Khan, M.S.I., Roy, S.S. and Pall, K.K., 2010, Acadmic journal of Plant Sciences, 3, 71-78.
21. Kirkby, E.A., 1981, Plant growth in relation to nitrogen supply. In Terrestrial Nitrogen Cycles. Processes, Ecosystem Strategies and Management Impacts, Eds. Clarke FE, Rosswall T, pp. 249—267. Ecol. Bull. Stockholm 33, Swedish Natural Science Research Council (NFR) Stockholm.
22. Lemaire, G., 2001, Ecophysiology of grassland: Dynamic aspects of forage plant population in grazed swards. In Proceedings of the XIX International Grassland Congress, Brazil, pp. 29 37. Sa˜o Paulo: SBZ.
23. Mac-Kinney, Y.G.G., 1941, J. Biol. Chem., 140, 315-322.
24. Marschner, H., 2002, Mineral Nutrition of Higher plants, 3rd Ed. Academic Press, London.
25. Mekki, A., Dhoub, A. and Sayadi, S., 2006, Microbiol. Res., 161, 93-101.
26. Mengel, K. and Kirkby, E.A., 1982, Principles of plant nutrition, In Potassium in Agriculture, 1985. Ed. RD Munson, p. 515. ASA-CSSA-SSSA, Madison, WI.
27. Moorby, J. and Besford, R.T., 1983, Mineral nutrition and growth, In: A. Lauchli, and R.L. Bieleski, (Eds.), Encyclopedia of plant physiology. 15B: New York: Springer Verlag. Pp. 481-527.
28. Murphy, M.D. and Boggan, J.M., 1988, Irish J. Agric. Res., 27, 83–90.
29. Rao, D.G. and Subramanian, V.B. 1990, Indian J. Plant Phy-siol., 33, 275-281.
30. Reddy, K.B., Reddy, D.S. and Reddy, C.M., 1991, Indian J. Plant Physiol., 34, 228-234.
31. Sadasivam, S. and Manickham, A., 1992, Biochemical Methods for Agricultural Sciences, Wiely Estern Ltd., Madras.
32. Saviozzi, A., Biasci, A., Riffaldi, F. and Levi-Minzi, R., 1999, Biol. Fertil. Soils., 30, 100–106.
33. Schmit, J.N., 1981, Le calcium dans le cellul generation en mitrose. Etude dans le tue pollinque en germination du clivia nobilis Lindl (Amaryllidaceae), C. R. Acad. Sci. Ser. (III) Higher Plants. Academic Press, London.
34. Singh, D.K. and Jain, S.K., 2004, Scientific Horticulture, 9, 97-100.
35. Sundara, B., Natarajan, V. and Hari, K., 2002, Field Crops Res., 77, 43–49.
36. Tak, H.I., Babalola, O.O., Maria, H.H. and Inam, A., 2013, Soil Science and Plant Nutrition, 1—12.
37. Taylor, G., McDonald, A.J.S., Stadenberg, I. and Freer-Smith, P.H., 1993, J. Exp. Bot., 44, 155–164.
38. Vanlauwe, B., Palm, C.A., Murwira, H.K. and Merckx, R., 2002, Agronomie, 22, 839–846.
39. Wang, C.H., Liem, T.H. and Mikkelsen, D.S., 1976, IRI Res. Inst., 48, 9–30.
40. Wolf, D.D., Kimbrough, E.L. and Blaser, R.E., 1976, Crop Sci., 16, 292-298.
41. WRI, 1994, World Resources 1994-95, Wasington, DC: World resource Institute. In: Agricultural sustainability, Principles, Processes, and Prospects. pp. 1. Raman, S. Food Product Press, New York.