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Plants absorb most of the essential nutrients from the soil, which is their primary source. Thus, the raising of crop plants year after year in the same field results in their deficiency especially N, P and K, if not added adequately and regularly (Miller and Donahue, 1990). Therefore, the judicious supply of nutrients can play an indispensable role in the realization of the full genetic potential of the growing crop (Milthrote and Moorby, 1979). Farmers pay considerable attention on fertilizers both organic and inorganic for obtaining the high productivity. It may be emphasized that the kind as well as the amount of the fertilizer to be applied depends, to a large extent, on the type of the crop grown and mode of its application. The thrust in this thesis was basically on plant nutrition and wastewater the latter being used as common resource of nutrients and water. Therefore, this chapter has been divided into five sections (1) plant nutrition and wastewater, (2) plant nutrition and inorganic fertilizers (2.1) nitrogen, (2.2) phosphorus and (2.3) NPK, (3) nutrient potential of wastewater and cumulative effect of NPK, (4) crop response, (4.1) growth response, (4.2) cutting response, and (5) conclusions.

5.1 Plant nutrition and wastewater (Experiments I-VI)

In general, the wastewater proved a good source of nutrients (Tables 8-101) as its application improved the performance of both vegetables. This improvement may be ascribed to the regular supply of some of essential nutrients from the irrigating wastewater. It seems that the wastewater provided more chances to roots for exploring the soil colloids and soil solution both for the availability of nutrients as well as of water. It may be pointed out that proper management of nutritional inputs, like balanced ratio and timely supply along with required water, are among the few important factors for getting better harvests. In fact, the wastewater specially when mixed with sewage may act as a liquid manure and therefore, may be helpful to crops, like grasses, silage and leafy vegetables, of which the desired vegetative growth may take place because of the presence of most essential nutrients specially the N, P and K. While the observed deleterious effect of the wastewater, when applied with higher fertilizer doses (N$_{20}$ and N$_{30}$ in fenugreek and N$_{60}$ in spinach) may be due to the
nutrients crossing their critical limits therefore, became excessive as sufficient amount of N was also present in soil (Table 5) as well as in wastewater (Table 6). It was further observed that for both crops, leguminous (fenugreek) and non-leguminous (spinach), 100%WW was more beneficial than 50%WW or GW (Experiments I-IV). This observation was not surprising as 100%WW was already diluted at several places due to the mixing of household wastewater and sewage water before it reaches to the main drain leaving the city where most of the vegetables are grown (Fig. 2a, b) for local consumption as well as for marketing to nearby cities like Delhi and Agra. Thus after 50% dilution, the concentration of nutrients present in the wastewater was further decreased and thereby giving comparatively lower yields than the 100%WW. The data of Experiments V and VI further confirmed that 100%WW was more effective (Tables 72 to 101) than 50%WW. Moreover, the irrigation even with 50%WW proved better to GW as noted in Experiments I to IV confirming the utility of wastewater as a good source of nutrients.

The beneficial effect of the wastewater is not far to seek. It contained in addition to the three major elements NPK, some other essential elements like S, Ca, Mg and Cl which might have contributed towards the improvement of growth specially the shoot fresh weight (Tables 12, 28, 44, 60, 72 and 87) and leaf number (Tables 14, 30, 46, 62, 74, 89) which are so important for the marketing of two leafy vegetables. Roles of NPK will be explained later while discussing them under section 2 of this chapter. Considering the remaining nutrients, S is the main constituent of some aminoacids, several coenzymes and prosthetic groups and its deficiency can cause a decrease in chlorophyll content (Dietz, 1989), therefore, its presence in the wastewater has increased chlorophyll content in both crops (Tables 16, 32, 48, 64, 75, 91). Similarly, Ca, playing important roles, among others, an essential component of cell wall, and its involvement in cell division (Schmit, 1981) would have enhanced shoot fresh weight and it also improved nodulation which was also observed by Lowther and Lonergan (1968). Similarly Mg a central atom of chlorophyll is required for structural integrity of chloroplast (Moorby and Besford, 1983) on which rate of photosynthesis also depends and thus may be responsible for the enhanced photosynthetic rate in the wastewater treated plants (Table 81-83, 97-99). Chlorine plays an important role in stomatal regulation and its deficiency may result in the reduction of leaf area and dry weight (Marshner, 2002), hence higher value of
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stomatal conductance in the wastewater treated plants (Table 82 and 98). Similar views on the beneficial effect of the wastewater on various crops were expressed by Pradhan et al. (2001) Ahmad (2004), Saeed (2004), Shah et al. (2005), Azad (2006) and Tabassum et al. (2007) while working on crops like wheat, gram, moong, triticale, lentil and mustard.

On testing the wastewater for microbes, it was found that it had some pathogenic bacteria. Mean value of at least three samples indicated the most probable number of coliform $2.1 \times 10^2$ $100$ ml$^{-1}$ of wastewater. Similarly, Salmonella and Shigella sp. was $3.20 \times 10^1$ $100$ ml$^{-1}$ which indicated the presence and survival of potentially pathogenic bacteria. Although no guideline is available for such bacteria for irrigation purpose. Thus on the basis of microbiological quality assessment of wastewater it may be concluded that:

1. Careful handling and proper washing of these leafy vegetables at the time of their cutting must be taken up before marketing.
2. The wastewater may be recommended to be used for irrigating fodder crops, pasture crops and such vegetables which are used only after cooking.
3. Further investigation for the presence of protozoan cysts and other microbes may be helpful. Monitoring of such wastewater should be mandatory by the local and state level governing bodies.

5.2 Plant nutrition and inorganic fertilizers (Experiments I-VI)

5.2.1 Nitrogen (Experiments I and II)

It is the most important nutrient as it is a major limiting element for growth. It increases the number and size of meristemic cells leading to leaf expansion and number (Gastal and Nelson, 1994) and a necessary component of several key biomolecules (Salisbury and Ross, 1992). It also enhances green colour of the leaf and succulence while delays flowering and fruiting eventually making it highly desirable for the production and marketing of leafy vegetables. Therefore, in Experiment I, the increase in growth (Tables 8-15), physiology (Tables 16-21) and yield parameters (Tables 22-24) was observed with lower dose ($N_{10}$) proving optimum. Since fenugreek is a leguminous crop and was able to fix its own nitrogen, therefore it does not require a heavy dose that checks the nodule formation (Mann, 1968; Arrese Igor
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et al., 1997; Ram and Verma, 2001). This observation is contrary to earlier observations on the same crop undertaken by Pareek and Gupta (1981), Banafar et al. (1995), Halesh et al. (1998), Chaudhary (1999a,b), Thapa and Maity (2003; 2004) where in comparatively higher rates of N (up to 60 kg h⁻¹) were reported. In the present study it may be because of the presence of two ionic forms of N supplemented through the wastewater (Table 6) in addition to available N of the soil (Table 5) which could have played important roles by maintaining adequate cation-anion ratio even under low fertilizer dose and therefore, the two comparatively higher doses (N₂₀ and N₃₀) proved excessive and thus lowering the shoot fresh weight (Table 12; Fig 3) shoot dry weight (Table 13), leaf number (Table 14), flower and pod number (Table 15). It may also be noted that the optimum dose also enhanced the root growth (Table 9) which might have increased the nutrient uptake (Tables 19-21) and nodulation (Table 11). This was also borne out by the strong positive correlation coefficient (r values) between the root fresh weight and N uptake (r = 0.863**, 0.964** and 0.979**), P uptake (r = 0.902**, 0.856** and 0.963**) and K uptake (r = 0.918**, 0.921** and 0.906**) and nodule number (r = 0.872**, 0.948** and 0.950**) at vegetative, flowering and fruiting stages respectively. On the other hand, the crop grown without N (N₀) expectedly gave significantly lowest values for the various parameters as some starter dose of N is always needed even by the leguminous crops to obtain satisfactory crop yields (Mengel and Kirkby, 1996).

In contrast to fenugreek, spinach (Experiment II) required comparatively more N (N₄₀) expectedly being a non-leguminous crop (Table 25-31). References were available where similar observations were reported by Wang and Li, 2004; Lise et al., 2005; Yingpeng et al., 2005 and Lefsrud et al., 2007. When its supply was suboptimal, the growth remained retarded thus N₂₀ proved deficient recording lower values for root fresh weight (Table 26), root dry weight (Table 27), shoot fresh weight (Table 28; Fig 3) shoot dry weight (Table 29), leaf number (Table 30) and leaf area (Table 31). On the other hand, N₆₀ seemed to be the luxury dose as it could not enhance the growth further (Milthrope and Moorby, 1979). As, NR activity depends on the availability of the substrate in cytoplasm, level of functional NR including the availability of cofactor (Campbell, 1999), therefore increase in NR activity may be due to the increased absorption and translocation of N to leaves (Tables 17 and 33) and nitrate assimilation. This proposition is also strengthened by correlation between
Fig. 3. Effect of GW, 50%WW and 100%WW on shoot fresh weight of *Trigonella foenum graecum* cv. Desi and *Spinacea oleracea* cv. Kaveri with four levels of nitrogen at vegetative (A) flowering (B) and fruiting (C) stages of growth.
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NR activity and N content \( r = 0.750^{**}, 0.838^{**} \) and \( 0.825^{**} \) in fenugreek. Enhanced activity of CA (Tables 18 and 34), a zinc metalloenzyme which catalyzes the hydration of CO\(_2\), was also observed although it is not dependent on nitrogen while its activity is highly dependent on Zn supply (Ohki, 1976).

The status of nutrients within plants may be assessed by leaf analysis as leaves may serve as a tool for diagnosing nutrient availability in the soil. In the present study, the leaf analysis showed enhanced NPK contents under optimum N application in both the crops (Tables 19-21 and 35-37). The presence of these essential nutrients in the soil, wastewater and their supply in the form of urea, superphosphate and muriate of potash were synergistically responsible for this increase. In addition, the enhanced root area of treated plants was also helpful in extracting more nutrients present near the root zone leading to higher dry matter (Tables 10 and 27). Similar positive interactions between N and P were also noted by Russell (1973) and between N and K by Murphy (1980). Seed yield was not the main objective of the present study although fenugreek and spinach seeds have their medicinal value as pointed out in Chapter 1. Since N was the main nutrient responsible for enhanced leaf area, leaf number and chlorophyll content, therefore it had the ability to contribute more photoassimilates and partition them efficiently into the harvested organ producing more pod number (Table 22), 1000-seed weight (Tables 22 and 38) and seed number (Tables 22 and 38) which in turn culminated into higher seed yield (Fig. 4), protein and carbohydrate contents (Table 24).

5.2.2 Phosphorus (Experiments III and IV)

It stands second in plant nutrition and has significant role in energy transfer via ATP. It helps in maturation of crops and formation of seeds in addition to root growth and nodulation (Patnaik, 1987). Among essential nutrients, it is often limiting due to low availability, therefore, its supply by any means particularly at later stages of growth has enhancing effect as also observed in these experiments (Fig. 5). In fenugreek, \( P_{40} \) was more effective, although even 90 kg P ha\(^{-1} \) was observed as optimum (Halesh \textit{et al.}, 2000), for root fresh weight (Table 41), root dry weight (Table 42), nodule number (Table 43), shoot fresh weight (Table 44), shoot dry weight (Table 45), leaf number (Table 46) and flower number (Table 47). However, comparatively less P was required by spinach as \( P_{30} \) enhanced most of the growth.
Fig. 4. Effect of GW, 50%WW and 100%WW on seed yield of *Trigonella foenum graecum* cv. Desi and *Spinacea oleracea* cv. Kaveri at harvest in Experiment 1 (A), Experiment 2 (B), Experiment 3 (C), Experiment 4 (D), Experiment 5 (E) and Experiment 6 (F).
Fig. 5. Effect of GW, 50%WW and 100%WW on shoot fresh weight of *Trigonella foenum graecum* cv. Desi and *Spinacea oleracea* cv. Kaveri with four levels of phosphorus at vegetative (A) flowering (B) and fruiting (C) stages of growth.
parameters (Tables 57 to 63). The adequate supply seemed to be responsible for enhanced leaf development leading to more leaf area and fresh weight. The correlation studies also show a strong positive relation between leaf number and shoot fresh weight at vegetative, flowering and fruiting stages \((r = 0.920^{**}, 0.932^{**} \text{ and } 0.811^{**})\) in Experiment III and \((0.925^{**}, 0.998^{**} \text{ and } 0.992^{**})\) in Experiment IV. This good response of growth characteristics seems to have manifested cumulatively through favourable partitioning of photosynthates towards the seeds, recording maximum seed weight and seed yield (Table 54 and 55). Contrary to sufficiency level, plants suffering from P deficiency may show reduction in leaf expansion and leaf area (Fredeen et al., 1987), leaf number (Lynch et al., 1991) and photosynthetic activity and activity of various enzymes (Avdeeva and Andreeva, 1974) thereby affecting the growth and yield adversely. This may also be seen from the perusal of data of Table 40 to 56 and 57 to 71. Treatment P20 was deficient giving lower values. The data also revealed that treatment P60 and P40 could be accounted for the luxury consumption in fenugreek and spinach respectively as these doses neither increased nor decreased the observed parameters significantly.

Unlike N, the beneficial effect of P on leaf NR activity seems to be indirect, as P in leaf tissue is known to be responsible for phosphorylation and release of photosynthates from chloroplast and oxidation of these sugars generating more reducing power for nitrate metabolism (Kow et al., 1982). An increase in the NPK contents of leaves because of P may be due to increase in root growth (Table 41 to 43). Strong positive correlation between N content \((r = 0.883^{**}, 0.952^{**} \text{ and } 0.954^{**})\) in Experiment III with root fresh weight at vegetative, flowering and fruiting stages respectively confirmed the above proposition. In addition, higher nodulation could have increased the N contents through more N fixation (Table 51). Similar increase was also reported by Jat et al. (1998) and Kumarawat et al. (1998) in fenugreek. While the increase in seed yield (Fig. 4) was obviously due to the enhanced yield components (Tables 54 and 70). This was also borne out form correlation studies wherein shoot fresh weight was positively correlated with seed number \((r = 0.975^{**}, 0.975^{**} \text{ and } 0.916^{**})\) in Experiment III and \(r = 0.976^{**}, 0.989^{**} \text{ and } 0.990^{**}\) in Experiment IV) and seed yield \((r = 0.976^{**}, 0.977^{**} \text{ and } 0.989^{**})\) in Experiment III and \(r = 0.973^{**}, 0.946^{**} \text{ and } 0.944^{**}\) in Experiment IV) the increase in seed protein
5.2.3 NPK (Experiments V and VI)

Finally the effect of N alone, N, P and NPK together was observed and the combined dose $N_{10}P_{40}K_{40}$ proved optimum for fenugreek (Tables 72 to 86), while comparatively higher level of N and lower levels of P and K ($N_{40}P_{30}K_{30}$) were found to be best for spinach (Tables 87 to 101). As pointed out earlier fenugreek is a leguminous crop and thus the lower N dose was probably sufficient while spinach being a non-leguminous crop required comparatively more N. On the other hand, fenugreek needed comparatively more P and K than spinach and this was not surprising as both crops differ for their fertilizer requirement. Such a difference can be attributed to their genetic variation and arise due to differences in efficiency of absorption from the medium of their rooting and utilization of these nutrients. There are references wherein different crops or genotypes have been found to differ markedly not only in their fertilizer requirement but also in absorption and distribution in various parts as reviewed by Epstein and Jefferies (1964), Langer (1966) and Clarkson and Hanson (1980). These two treatments, $N_{10}P_{40}K_{40}$ and $N_{40}P_{30}K_{30}$, thus proved best as both combinations have optimums of N and P and thus confirming earlier findings of Experiments I to IV. The cumulative effect of these essential macronutrients seemed to be responsible for the good performance of fenugreek and spinach (Fig.6). In this context, mention may be made of Russell (1973) who pointed out that "If two factors are limiting or nearly limiting growth, adding only one of them will have little effect on growth whilst adding both together will have considerable effect. Two such factors are said to have a large positive interaction in such circumstances for the response of crop to both together is larger than the sum of response of each separately". On similar line Kilcher (1965) also observed that the combination of N and P resulted in higher yield than obtained under N alone. In the present study although N alone was better than control but it was less productive in comparison to the doses where N, P together were given which in turn were less productive when N, P, K in combination were given.
Fig. 6. Effect of 50%WW and 100%WW on shoot fresh weight of *Trigonella foenum graecum* cv. Desi and *Spinacea oleracea* cv. Kaveri at 30 DAS (A), 45 DAS (B), 60 DAS (C) and 75 DAS (D) cuttings.
5.3 Nutrient potential of wastewater and cumulative effect of NPK

As pointed out earlier wastewater had sufficient nutrient contents and when it was supplemented with inorganic fertilizers, significant improvement in both the vegetables was observed. Thus, there were instances where 100%WW was as effective as groundwater supplemented with some inorganic fertilizers. Mention may be made of 100%WWxN0 giving at par values to GWxN20 in root fresh weight (Table 9), leaf number (Table 14) and chlorophyll content (Table 32). Similarly, 100%WWxP0 was at par with GWxP20 in branch number (Table 70a) and seed number (Table 70b). Likewise 100%WWxN0 gave 3.88 and 3.25% more N content than GWxN0 (Table 19) and 100%WW improved 1000-seed weight over GW (Table 22d and 38c). Enhanced nodulation by 100%WWxP0 over GWxP0 (Table 43), increased shoot fresh weight (Table 44) and improvement in chlorophyll and NPK contents by 100%WW over GW (Table 48, 51, 52 and 53) may also pointed out. Similarly enhancement in protein content (Table 56a), shoot fresh weight (Table 60) and leaf number (Table 62) by 100%WWxP0 over GWxP0, indicates the beneficial effect of wastewater in the over all growth and development of the two vegetable crops while observing experiments I-IV. In the following experiments (V and VI) the cumulative effect of N, P and K applied together was more pronounced when given with the wastewater. The data of Table 74 and 78 showed that 100%WWxN0P0K0 was at par with 50%WWxN0P0K0 and the data of Tables 72, 84a, 84b, 84c, 85a, 85b, 86a, 87, 88, 100c revealed that 100%WWxN0P0K0 gave the marginal increase over 50%WWxN0P0K0. These results, thus prove the efficacy of 100%WW over 50%WW in both the experiments. Out of twelve interactions, combination of 100%WW with the doses of NPK at their optimums N10P40K40 in case of fenugreek and N40P30K30 in case of spinach proved most effective, confirming our assumption, as pointed out in Chapter 1, that the wastewater can be considered as a source of nutrients and may also be helpful if given with judicious doses of NPK (Table 89).

5.4 Crop response (Experiments I-VI)

5.4.1 Growth response (Experiments I-IV)

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and leaf number (Tables 14, 30, 46 and 62) was increased up to the last sampling. However, the growth was comparatively faster during vegetative to flowering period in comparison with flowering to fruiting period. This pattern of growth may be attributed to the sigmoid growth, i.e. the faster cell division and differentiation in the log phase (vegetative to flowering) of growth period in comparison with the slow growth rate afterwards (flowering to fruiting). Contrary to this in II and IV experiments (spinach) leaf size (leaf area leaf^{-1}) was decreased from flowering to fruiting but leaf number was increased hence the total leaf area on per plant basis (Tables 31 and 63). The increase in nodule number up to flowering only (Tables 11 and 43) may be ascribed to the fact that initially the competition for photosynthates was confined to roots, nodules and aerial vegetative organs, however, when flowering and fruiting started, new sinks have provided more demanding sites for the photosynthates, thus creating shortage for the nodules, as a result of which their degradation started. Similarly, flower number in fenugreek decreased after the onset of fruiting (Table 15 and 47, Experiment I and III). This decrease was more pronounced in the control (no fertilizer) under both waters due to the phenomenon of flower fall which might have resulted from the non-availability of sufficient nutrients. In contrast, decrease in chlorophyll content (Tables 16, 32, 48 and 64), NR activity (Tables 17, 33, 49 and 65) and CA activity (Tables 18, 34,50 and 66) was noted with the increase in age of both crops and the decrease was low between vegetative and flowering and high between flowering to fruiting which may be attributed to the differential mobilization of organic and inorganic substances to sink. Moreover, the concomitant increase in leaf area would have also increased the capacity of the sink. These results also corroborate the findings of Hesketh et al. (1981), Bhagsari and Brown (1986), and Davies et al. (1987). The decrease in leaf N (Tables 19, 35, 51 and 67), P (Tables 20, 36, 52 and 68) and K (Tables 21, 37, 53 and 69) contents with the advancement of the growth of two crops may be due to the dilution factor because of increased growth and redistribution of these nutrients to younger plant parts. In addition, the translocation of nutrients to sink (seeds) during their formation may also be responsible for such observation. Mention may be made of the work of Gomide et al. (1964) on six tropical grasses wherein a decline in the leaf P concentration with growth was observed. Similarly, a rapid decline in the leaf K concentration with maturity in forage legume herbage was reported by Rhykerd and Overdahl (1972).
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Among the three nutrients, K was accumulated more followed by N and P. In this context, it may be of interest to note that for higher plants, K is the most abundant cation of the plant tissues (Huber, 1985) due to its higher solubility, easy availability and greater permeation rate. Peavy and Grieg (1972) also noted that the removal of K was more than P and N in spinach. Similarly, Widdwoson et al. (1981) and Mengel and Kirkby (1982) reported that the uptake of K was more than P and N in various vegetables like potato and tomato. It may, therefore, be pointed out that such variations in mineral contents are influenced by various factors including the type of crop and even varieties their growth habits, root systems, the ability to absorb nutrients present near root zone and ofcourse the composition of the medium in which the plants grow.

5.4.2 Cutting response (Experiments V and VI)

Green leafy vegetables are normally harvested by clipping of the leaves and young shoots and repeated cuttings may be taken during one growing season, while for seeds, the crop is left without clipping. Generally, two cuttings have been reported to be undertaken (Baboo, 1997 and Thapa and Maity, 2003; 2004), however, in the present study (Experiment V and VI), three cuttings could be possible if these vegetables are grown with wastewater. This was probably due to the regular supply of nutrients through irrigation leading to regular increase in leaf number, leaf area, shoot fresh weight and physiological parameters of the two crops. Iqbal et al. (1994), studying the effect of municipal wastes on spinach and coriander, also reported similar findings. Unlike growth parameters, increasing number of leaf cuttings decreased the pods number plant$^{-1}$, seed number pod$^{-1}$,1000 seed weight and seed yield (Tables 84-85) and branch number plant$^{-1}$, seeds number plant$^{-1}$ and 1000 seed weight (Tables 100-101; Fig. 4). Datta et al. (2005) and Kumar and Singh (2007) also reported while physiological parameters (Tables 75 to 83 and 91 to 99) were increased possibly to cope up the growth of the cutted plants.

5.5 Conclusion

Apart from the importance in enhancing the crop production, use of wastewater is of much wider importance when judged for the preservation of productivity of agricultural land and environment. Increased growth and yield by such waters undoubtedly saves fertilizers and expenditure but the whole question of productivity
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can not be viewed from the narrow angle of immediate yields and the amount saved. In our opinion application of sewage water alone or blended with some city wastewater, as in the present study, can be placed under the organic manuring to some extent as chemical fertilizers can not contribute to the maintenance of soil environment capable of stimulating favourable biological activities in addition to improvement in physical condition of soil and aggregation of its particles. Such manurial liquid wastes may, therefore be necessary for agricultural lands in the countries where chemical fertilizers are not easily available due to their import from other countries and because of their high cost which is normally beyond the reach of common poor small farmer. The present study had therefore, established beyond doubt, that this wastewater without any dilution was capable of producing higher yields compared with that raised under normal irrigation water and even better after using some amount of inorganic fertilizers. Further conclusions based on the findings of experiments I-VI may be drawn as follows:

1. Physico-chemical analysis of the wastewater revealed its suitability for irrigation because most of the values were within the permissible limits of CPCB of irrigation water. In the present study, the conductivity of the wastewater was up to 1400 $\mu$ mhos cm$^{-1}$, therefore it may be classified as medium saline and thus may be safe for irrigation as up to $2250 \mu$ mhos cm$^{-1}$ can be used in agriculture which is a lower limit of high salinity.

2. Use of the wastewater in agriculture can be attributed to the fact that it contained a sufficient amount of essential nutrients specially the NPK thus minimizing the inorganic fertilizer requirement.

3. It may prevent the fresh water degradation due to eutrophication.

4. It may also reduce the burden on fresh water resources and 100%WW proved better than 50%WW, therefore, further dilution was not necessary.

5. The microbiological examination of the wastewater revealed the presence of some pathogenic micro-organisms due to which growers may be warned. Since the crop is not eaten uncooked, therefore, there may not be any harm to consumers.
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6. The soil was sandy loam in texture and also contained some of the essential nutrients with medium alkaline pH which makes it suitable for vegetable cultivation.

7. In Experiment I (fenugreek), N_{10} proved optimum, while N_{20} and N_{30} were excessive for most of the important parameters, including nodule number, shoot fresh weight, leaf number, seed yield, protein and carbohydrate contents, with 100\%WWxN_{10} proving best.

8. In Experiment II (spinach), N_{40} gave the optimum performance, with N_{20} being deficient and N_{60} excessive mainly for shoot fresh weight, leaf number, leaf area and seed yield. Among interactions, 100\% WW x N_{40} was most effective combination.

9. In Experiment III (fenugreek), P_{40} gave the maximum values and P_{60} was generally at luxury consumption, whereas P_{20} was the deficient dose. The combination 100\%WWxP_{40} was the best among all interactions.

10. In Experiment IV (spinach), comparatively lower dose P_{30} was the optimum, with P_{40} proving luxury and P_{20} the deficient one. Out of interactions, 100\%WWxP_{30} was the most beneficial.

11. In Experiment V (fenugreek), for most growth and yield parameters including shoot fresh weight, the optimum doses of N and P obtained in Experiments I and III along with K_{40} proved best, with the interaction 100\%WWxN_{10}P_{40}K_{40} being the most effective combination.

12. While in Experiment VI (spinach), the dose having comparatively more N and less P and K, N_{40}P_{30}K_{30} proved better for most of the parameters studied and this combination further improved the growth and yield parameters when applied with the wastewater.

13. In Experiments I to IV, plant height, fresh and dry weights, leaf number leaf area (Experiment II, IV) increased with the advancement in plant age, while nodule number (Experiment I, III) increased up to flowering only. However, total chlorophyll content, NR activity, CA activity and leaf NPK contents decreased with the advancement in age of the plants.
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14. In Experiments V and VI, the growth was maximum at the third cutting due to regular supply of nutrients through the wastewater, therefore in all three cuts may be taken up.

15. Among the three nutrients, K accumulated more in leaves followed by N and P.

The wastewater, therefore, can be utilized as an alternative source of irrigation without any dilution as it can be pumped directly from the wastewater drain with N10P40K40 and N40P30K30 proving best for cultivation of fenugreek and spinach respectively.

Proposals for future studies

The observations recorded during three years of this study have helped in understanding the utility of the wastewater in agriculture, however, still there remain some areas where work may further be undertaken on the following lines:

1. These trials may be undertaken in the field conditions, if possible, near the wastewater drain with the coordination of local farmers to confirm the findings of the pot experiments.

2. Some of the heavy metals may be analysed in the wastewater, soil and plants, specially Ni, Cr and Pb as the city wastewater was mixed with the nickel plating industrial wastewater.

3. Further study on microbiology of the wastewater may also be undertaken.

4. Leghaemoglobin content and nitrogenase activity may be determined to estimate the N-fixation ability of fenugreek.

5. Ascorbic acid and mineral contents including Fe may be estimated in spinach in addition to carbohydrate and protein in the leaves of both the crops.