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Evaluation of water and nutrient use efficiency in broccoli through fertigation

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Abstract
A field experiment was conducted in sandy loam soil to investigate the water and nutrient use efficiency of Sprouting Broccoli grown on sandy loam soil using fertigation. The treatments included application of the recommended fertilizer dose as soil application and irrigation through drip system as well as three levels of fertigation 100, 80 and 60 percent of recommended fertilizer doses. Flood irrigation with the recommended fertilizer dose was treated as control. Water and nutrient profiles were monitored horizontally and vertically at various crop stages. The results indicated that through drip irrigation the soil water status was maintained at optimum level in the root zone of the crop (0-50 cm) which extended up to 30 cm horizontally from the plant. Nitrate concentration was maximum below the emitter decreasing as the wetting zone moved away from the emitter. Yields obtained indicated that substantial savings in the fertilizer applied, to the extent of 20 to 40 percent, could be accomplished through fertigation. The spatial distribution of nitrate and water content indicate that designing the drip system is very important in fertigation studies for maximizing the fertilizer use efficiency.

Keywords: Water, nutrient use efficiency, broccoli fertigation

Introduction

Water and fertilizer are the two costliest inputs in agriculture. Apart from the economic considerations, it is also well known that the adverse effect of injudicious use of water and fertilizers on the environment can have far reaching implications. There is therefore a need for technological options which will help in sustaining the precious resources and maximizing crop production without any detrimental impact on the environment.

Among the various techniques developed for application of water, drip irrigation also referred to as trickle irrigation or micro irrigation is gaining popularity as perhaps the most efficient method of water application (Bucks *et al*., 1982; Bhagat et. Al. 2014) [3, 2]. Initial investment is high and therefore to encourage adoption of this technology, the Government of India is providing a subsidy ranging from 70 to 90 percent making it an attractive proposition. The area under drip irrigation which was over 70 thousand hectares in 1994 (INCID, 1994) [11] is now around 2 lakh hectares. As water labour and land preparation become costlier this technique of water application is bound to replace conventional systems. It has been reported that the savings in irrigation water using this technique over the savings in irrigation water using this technique over conventional methods can range from 40 to 70 percent (Chowdhury, 1992) [4].

Drip irrigation has another advantage that it can also be used to apply any water soluble fertilizer or chemical in precise amounts, as and when required to match the plant needs, directly into the root zone of the crop. This is usually referred to as Fertigation or Chemigation. Consequently, injection of fertilizer provides a means of improving nutrient use efficiency as the fertilizer applied remains confined to the root zone of the crop.

In recent years, considerable amount of work has been conducted on the use of drip irrigation in the country (INCID, 1994) [11] but the studies on the nutrient movement and distribution using drip irrigation are very few. Sprouting Broccoli is a very high value crop gaining popularity in commercial farming but very little work has been done on it.

Very limited literature is available on micro irrigation as well as fertigation in Broccoli either from India or abroad. In this paper an attempt has been made to evaluate the growth and yield of Broccoli under drip made to evaluate the growth and yield of Broccoli under drip irrigation, fertigation and conventional method of irrigation.

Materials and Methods

A field experiment with Sprouting Broccoli was carried out at the experimental farm of the Hi-Horticulture located in Rajendra Agricultural University, Pusa, Samatipur, Bihar The soil is classified as Typic Ustocrept having sandy loam texture with the average pH and EC of the 1:2:5 soil water suspension ratio being 7.51 and 0.48 respectively. The organic carbon content was 0.32 percent.

The crop Sprouting Broccoli (*Brassica oleracea* var. *Italica* L.) Variety - Packman; was sown in the nursery on 15th October, 2012 transplanted in the field on 20th November, 2012 and harvested on 14th February, 2013. The plant to plant spacing was 30 cm while the row to row spacing was 60 cm. All necessary measures were taken to keep the crop pest free. The marketable yield of Broccoli was taken as the total fresh weight at harvest.

The following five treatments replicated four times were adopted for the study:

T_1: Fertigation with 100 percent dose of fertilizer in four equal splits;

T_2: Fertigation with 80 percent dose of fertilizer in four equal splits;

T_3: Fertigation with 60 percent dose of fertilizer in four equal splits;

In all these three treatments the first dose of fertilizer was applied on 28th December, 1996 i.e. 10 days after transplanting and the remaining three applications were made on 23rd December, 2012, 12th January, 2013and 29th January, 2013 i.e. at 0,20 and 17 days interval. AHaisol Green≅ fertilizer was used for fertigation.

T_4: Drip irrigation with fertilizer as specified in the check basin treatment below.

T_5: Check Basin.

Half of the recommended N as basal with full dose of P and K time of transplanting followed by 1/4 N as 1st top dressing at 30 days after transplanting and 2nd split (1/4 N) at 60 days after transplanting were given.

The recommended fertilizer dose of N: P: K taken as control in T_4 and T_5 was 200:125:150 kg per hectare.

In drip system water was applied based on the evapotranspiration demand of the crop computed from the daily Pan evaporation values (Doorenbos and Pruitt, 1977) [7] every alternate day. For check basin treatment, water was applied on the basis of soil moisture tension value (0.03 Mpa approximately) measured by tensiometers installed in the field at 25 cm depth.

The size of the experimental field was 30m x 18m of which 30 m x 2.4 m was under drip irrigation and fertigation treatments (T_1 to T_4) and 36 m^2 was under check basin (T_5). T_1 to T_4 treatments were divided into four replications of 7.5 x 2.4 m^2 each. Each of the four check basin plots was of 3 m x 3m dimension.

During the crop growth period, observations were taken on moisture content, ammonium and nitrate concentrations in the various soil layers. Sampling was done from 0-5, 5-10, 10-20, 20-30, 30-50, 50-70 and 70-90 cm depth of the profile at the emitting point and 15,30, 45 and 60 cm horizontally away from the emitting point. The drip line was placed mid-way between the two rows of Broccoli plants. Moisture content of the samples were determined gravimetrically and nitrate and Ammoniacal - N by Teacher Automated 5020 Flow Injection Analyser.

Plant samples were collected at each fertilization stage and at harvest. Fresh and Dry weight were record and nitrogen contents were determined by Kjeldahal Steam distillation method.

Result and discussion

Water movement and distribution

In the treatments T_1, T_2, T_3 and T_4 the amount of water added through the drip system was almost identical while in case of the T_5 (check basin) treatment, it was relatively higher and applied at less frequent intervals. The total amount of water applied per in all the drip irrigation and fertigation treatments (T_1, T_2, T_3 and T_4) was 38.1 lt/plant while in check basin, it was 55.0 lt/plant. The resultant distribution pattern of soil water for drip irrigation, fertigation and check basin irrigation is depicted graphically in figures.

The resultant soil water content profiles in T_1, T_2, T_3 and T_4 indicated that the soil water content was relatively higher near the emitter throughout the experiment. The soil water content decreased as the distance from the emitting point increased. The differences in the soil water content in the various treatments below the 30 cm depth disappeared and a fairly uniform soil water content profile ranging from 20 to 25 percent by volume was maintained irrespective of the distance from the emitter. This soil water content represented a soi water content near the field capacity of the soil equivalent to soil matrix potential between -0.01 to -0.015 Mpa and indicates optimum soil water in the surface layers.

In the surface layer (<20 cm) the soil water content was reduced to 15 percent by volume approximately in the 0-5 cm layer before irrigation, but exceeded 20 percent in the surface layer up to a distance of 45 cm from the emitting point. Even at harvest the soil water content was uniformly distributed in the profile beyond 20 cm depth. Variations occurred in the surface layers due to evaporation loss. As the horizontal distance from the emitting point increased, the soil water content value decreased in the surface layers.

In the check basin treatment (T_5) nearly optimum conditions were maintained to avoid even a mild stress of water, but even then the soil water content rarely exceeded 20 percent after irrigation which was approximately a soil matrix potential of 0.03 Mpa. It generally averaged around 15 percent beyond 20 cm depth. There was no difference in the soil water content status near the plant and between the plants.

The soil water content profile in all the drip irrigation/fertigation treatments have shown that the soil moisture status remained at optimum level (tension 0.1-0.15 bar) throughout the profile (0-90 cm) indicating higher efficiency of the system in maintaining soil moisture regime for the crop growth in addition to savings in water application. It also resulted in savings of 17.1. lt water for every plant (30.73 percent over conventional methods). Similar results have been reported by number of researches in the past (Aggarwal and Dixit, 1972, Sivanappan *et al*., 1972, Sivanappan *et al*., 1987, Haynes, 1990, Prabhakar and Hebber, 1996) [1, 16, 17, 10, 15].

Nitrate (NO_3-N) movement and distribution

The spatial and temporal variation in NO_3-N concentration in soil, for T_1 treatment before and after each fertigation and at harvest is presented graphically.

The significant difference of NO_3-N movement and distribution observed between drip fertigation, drip irrigation and check basin treatments a few days following fertigation or fertilization was that the peak concentrations of NO_3-N in fertigation treatments were found at some depth in the profile (for the point near the emitter peak was formed at a greater depth than any other points following fertigation), where as maximum NO_3-N concentration in T_4 treatments was found in the surface layer gradually decreasing down the profile. The peak concentration for the points near the emitting points and 15 cm from that in T_1, T_2 and T_3 treatments was much more than that for other points. This range was not so large for T_4 treatment. For check basin treatment the peak concentration moved to a much lower depth than other treatments with drip system, indicating loss of NO_3-N out of the root zone which was found to be 10-50 cm. In both T_4 and T_5 treatments, urea was applied but for T_4, the water was applied through drip whereas in T_5, the flood irrigation system was employed. This resulted in the difference in the quantum of water applied at a time between the two treatments following application of fertilizer. Hence, NO_3-N moved to a greater depth greater than 50 cm with water in check basin (T_5) but in T_4, it was confined within 50 cm depth.

Ammonium (NH_4-N) movement and distribution

In check basin treatment (T_5), the peak was always found between 20-50 cm depth with minimum NH_4-N concentration in the surface layer (0-10 cm) which was in contrast with drip irrigation and fertigation treatments, were maximum NH_4-N concentration was always found in the surface layers.

It is only after the third fertigation that the changes in NH_4-N content percolate down to deeper layers. NO_3-N ions, on the other hand are considered very mobile. But unlike T_5 (check basin treatment) where the soil is comparatively drier, the higher soil water status in the root zone in T_1, T_2,T_3 and T_4 treatments restricts the mobility of NO_3 ions to the 20-30 and 30-50 cm layers. These results confirm to the observations of dalbro and Dorph-Peterson (1976) [6}, Joshi *et al*. (1976) [12], Focht and Verstraete (1977) [9] and Haynes (1990) [10], who have reported that solute penetration is more in an initially dry soil compared to an initially moist, soil.

In T_4 and T_5, the amount of fertilizer applied was identical but as a result of higher amount of water applied in T_5, a significant amount of fertilizer was leached down which was reflected in the relatively lesser amounts of NH_4-N and NO_3-N being retained in the profile. The soil profile was relatively drier in T_5 compared to other treatments and this resulted in the conversion of NH_4-N to NO_3-N the latter being mobile was leached down.

In T_1, the total amount of water soluble fertilizer applied in split doses was actually half of the total N-fertilizer applied in T_4 or T_5. That resulted in an initially higher NH_4-N and NO_3-N concentration in the soil in T_4.

The sum of NH_4-N and in the soil indicated that nitrogen is fairly uniformly available in the root zone of the crop up to nearly 30-40 cm. This highlights the advantages of fertigation in that the nutrient is more uniformly distributed and available to the plants.

It is often that nitrate ion being mobile has a tendency to move away from the emitter to the periphery of the water front (Dalbro and Dorph-Peterson, 1976) [6] and not be available to the plant. The distribution of NO_3-N in the soil profile has shown that it neither accumulates at the periphery of the wetting zone nor is leached out from the root zone under drip systems. The design of the drip irrigation system coupled with discharge rate can optimize both water and fertilizer use by a crop.

Yield of broccoli

The statistical analysis of the yield data revealed that fertigation level with 100 percent dose of fertilizer significantly affected yield than drip irrigation with conventional method of urea application. Fertigation with 100 percent and 80 percent dose of fertilizer showed significantly higher yield than fertigation with 60 percent dose of fertilizer. There was no significant difference of yield between fertigation with 100 percent and 80 percent dose of fertilizer.

The results indicated that drip fertigation was the most beneficial treatment for the growth and yield of broccoli in comparison to drip irrigation with urea fertilization and check basin irrigation with urea fertilization. Though soil application of urea along with drip irrigation showed more yield than check basin, the difference was not found to be statistically significant.

Water-use-efficiency

Water -use-efficiency (WUE) was defined as the marketable yield of broccoli per unit quantity of water applied. The applied water was expressed in mm. WUE was maximum (18.7 kg/ha-mm) in T_1, T_2, T_3 and T_4 minimum in T_5 (6.52 kg/ha-mm). The amount of water applied was identical in T_1, T_2, T_3 and T_4 and higher in T_5 but since the yield followed the order $T_1 > T_2 > T_3 > T_4 > T_5$, the WUE also showed the same trend. Differences in WUE between T_1 and T_2 not statistically significant. Variation in WUE in any of the drip fertigation treatments (T_1, T_2, and T_3) and drip irrigation treatment (T_4) with soil application of urea from was found to be statistically significant at 5 percent level indicating efficiency of water under drip system of irrigation over check basin irrigation.

Fertilizer-use-efficiency

FUE was highest in T_2 treatment followed by T_3 with the difference being non significant between T_2 and T_3. Variations in FUE was found to be statistically significant between T_1 and T_2 or T_1 and T_3. FUE was very low in T_5 (5.175) and T_4 compared to T_1, T_2 or T_3. There was no significant difference in a FUE between T_4 and T_5.

When the nitrogen-use-efficiency (NUE) was taken as a parameter, the same trend was observed. The NUE in the decreasing order $T_2 > T_3 > T_1 > T_4 > T_5$. As was the case of FUE, NUE was also highest in T_2 (48.80 kg ha^{-1} kg^{-1} N) being slightly lower in T_3 (48.45 kg ha^{-1} kg^{-1} N). Differences were significant between T_1 and T_2 or T_1 and T_3. The lowest NUE was 10.00 kg/ha found in T_5. The NUE increased significantly in all the T_1, T_2 or T_3 treatments as compared between T_4 and T_5 treatments was found to be statistically non-significant.

As in other vegetable crops including cole crops, fertilizer-use-efficiency increased order under fertigation (Parikh *et al*., 1996) [14] leading to not only savings in fertilizer application but also preventing leaching losses. The limited literature on broccoli also supports this observation (Everaarts, 1993) [8].

Conclusions

It can be concluded that by fertilizer application through drip system as in T_2, economy can be achieved in the total amount of water applied (30.73 percent water savings over check basin) as well as fertilizer application (20-40%). It is important to keep into the mind that the dose of fertilizer through drip system was actually 50 percent of the recommended dose to get a marketable yield which is significantly higher than drip irrigation with soil application of fertilizer and check basin with soil application of fertilizer. Fertigation is a promising technique for both water and fertilizer application and leads to economy in both as well as higher yields.

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