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Scheduling and standardization of fertigation techniques to improve the yield and quality of Lettuce (*Lactuca sativa* var. *capitata*)

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Abstract
Lettuce, *Lactuca sativa* L. belongs to the family Compositae and it is a hardy annual. It is used for salad purpose and called as king of salad vegetables. Due to the dynamics of quite uncommon development, short cultivation cycle with shallow root system and the need of transplant for establishment, nutrient application in lettuce requires great caution.As the crop is highly sensitive in terms of nutrient specifications and owing to its short life cycle there is a need to schedule and standardize an efficient nutrient application method like fertigation. Hence field experiments were conducted using lettuce hybrid 'Raider' (Seminis Seeds Pvt Ltd.) during November 2015 - January 2016 and March – May 2016 at Wood House Farm, Horticultural Research Station, Tamil Nadu Agricultural University, Ootacamund, India. The soil of the experimental site was clayey loam in texture, with electrical conductivity of 0.55 dsm^{-1} and 4.5 pH. The recommended dose of fertilizers (100:60: 60 kg NPK ha^{-1}) were scheduled based on the uptake pattern of lettuce and given at seedling stage, rosette stage and maturity stage in the ratio of 10:20:60. In control treatment, full dose of nitrogen, phosphorus and potassium were applied through straight fertilizers as soil application. In fertigation treatments, 75 percent recommended dose of phosphorus was given through soil application with straight fertilizers as basal dose and remaining 25 percent was applied as water soluble fertilizers through drip fertigation. The fertigation was given at five day intervals using water soluble fertilizers. The study revealed that fertigation with water soluble fertilizers at 100% RDF recorded the highest head weight (562.59 g), head diameter (14.01 cm) and yield (27.83 t/ha). Fertigation with water soluble fertilizers was found to improve the quality characters such as ascorbic acid content, nitrate content, calcium content, total carotenoid content, and total antioxidant content of lettuce head and physiological loss in weight of head was low in fertigation treatments compared to the soil application of straight fertilizers.

Keywords: Lettuce, Raider, fertigation, water soluble fertilizers, straight fertilizers

Introduction
Lettuce (*Lactuca sativa* L.) belongs to the family Compositae and it is a hardy annual. It is usually regarded as a derivative of the wild *L. scariola*. Crisphead a subtype with large heads is designated iceberg in the trade. Lettuce is used for salad purpose and is also called as king of salad vegetables. Efficient use of fertilizer and water is highly critical to sustained agricultural production. Fertilizers applied under traditional methods are generally not utilized efficiently by the crop. In fertigation, nutrients are applied through emitters directly into the zone of maximum root activity and consequently fertilizer-use efficiency can be improved over conventional method of fertilizer application. In recent times, farmers evince interest in growing exotic vegetables especially salads like lettuce in view of their enhanced quality, high marketable yield, market demand and ensured returns. The maximum genetic expression of potential yield is possible only when nutrition protocol during different critical stages of crop growth is refined. The macro nutrients (N and K) are reported to improve quality of lettuce heads. Not much information is available on fertigation improving quality characters of closely spaced crops like lettuce. Therefore, the present investigation was conducted to study the effect of fertigation on yield and quality characters of lettuce.

Materials and Methods
The field experiments were conducted using lettuce hybrid 'Raider' (Seminis Seeds Pvt Ltd.) during November 2015 - January 2016 (Crop I) and March – May 2016 (Crop II) at Wood House Farm, Horticultural Research Station, Tamil Nadu Agricultural University, Ooty India.

The experiment was laid out in a randomized block design with eight treatments replicated thrice. The treatments consisted of soil application with straight fertilizers (SF) at 100% RDF (T_1 - Control), fertigation with water soluble fertilizers at 100% RDF (T_2), fertigation with water soluble fertilizers at 75% RDF (T_3), fertigation with water soluble fertilizers at 50% RDF (T_4), fertigation with Water soluble Fertilizers at 25% RDF (T_5), soil application with SF at 25% RDF + fertigation with water soluble fertilizers at 75% RDF (T_6), Soil application with SF at 50% RDF + fertigation with water soluble fertilizers at 50% RDF (T_7) and Soil application with SF at 75% RDF + fertigation with water soluble fertilizers at 25% RDF(T_8). A plot size of 7.5 m^2 (7.5 m x 1.0 m) was followed for each treatment Raised beds of 1 m width and 20 cm height were prepared and thirty five days old healthy seedlings with a ball of coir pith were used for planting. The lateral was placed at the centre of each bed and the seedlings were planted in paired row system on both the sides of lateral adopting a spacing of 45 x 45 cm. The recommended dose of fertilizers (100: 60: 60 kg NPK ha-1) was taken as 100 per cent recommended dose of fertilizers. In control (T_1), full dose of phosphorus and potassium were applied as basal and nitrogen was applied in two splits of 30 kg each at basal and 30 DAT as soil application. The fertigation was given at five day intervals using water soluble fertilizers. 75 percent of phosphorus was given through soil application with straight fertilizers as a basal dose. After each harvest the quality parameters such as ascorbic acid (AOAC 1975) [1], nitrate content (Cataldo *et al*., 1975) [2], calcium content (Versenate method), total carotenoid content (Jensen, A. 1978) [3], total antioxidant content (Umamaheswari and Chatterjee (2008) [4], colour of head at harvest (CR-400, Konica Minolta) and physiological loss in weight were estimated.

Results and Discussion

Highest mean head weight (562.59 g) and head diameter (14.01 cm) were observed in the treatment combination of fertigation with water soluble fertilizers at 100% RDF (T_2) (Table 1). The reason might be fertigation with higher rates of water soluble fertilizers resulted in higher availability of nutrient ions in soil solution, which obviously would have led to increased plant growth, higher uptake of nutrients, better photo assimilation and better translocation of assimilates from source to sink leading to increased head weight and head diameter. This result is closely related to the findings of Cantliffe and Hochmuth (1997) [6] in iceberg lettuce and Marsic and Osvald (2004) [7] in cabbage.

In the present investigation highest (27.83 t ha^{-1}) of lettuce head was obtained in T_2 treatment (fertigation with water soluble fertilizers at 100% RDF) (Table 1) which was on par with T_6 (soil application with SF at 25% RDF + Fertigation with WSF at 75% RDF). This could be attributed to the fact that application of water soluble fertilizers through fertigation, was more effective in production of higher number of heads per plot by increased per cent head set and carrying set heads to maturity and harvest which has resulted in significant increase in yield per plot and per hectare. The increase in yield might be due to better proportion of air-soil-water which was maintained throughout the life period of crop in drip irrigation as compared to surface irrigation. Fertigation with higher rates of fertilizer resulted in higher availability of required nutrients in soil solution which obviously led to increased growth, leaf area, higher uptake of nutrients, better photo assimilation and better translocation of assimilates from source to sink which in turn increased the head yield. This result is in line with the findings of Marsic and Osvald (2004) [7], Kumar and Sahu (2013) [8] in cabbage. Less yield was recorded in the treatment of soil application with straight fertilizers at 100% RDF (T_1). This might be due to non-availability of nutrients to the crop by volatilization and fixation of nutrients in soil by soil application. This result is closely related to the findings of Gupta and Chattoo (2014) in Knol khol.

Fertigation with water soluble fertilizers at 100% RDF produced heads with highest ascorbic acid content (53.75 and 62.34 mg 100 g^{-1}), nitrate content (2436.35 and 2442.77 mg kg^{-1}), calcium content (15.45 and 16.72 mg 100 g^{-1}) (Table 1), total carotenoid content (0.39 and 0.41 mg g^{-1}), total antioxidant (4.05 µ mol AA g^{-1} and 4.19 µ mol AA g^{-1}) (Table 2) in crop I and crop II respectively. Fertilizer application method and also type of K fertilizer applied had a positive impact on ascorbic acid concentration in head due to the better availability of K to the plant. This is consistent with the research findings of Hebbar *et al.* (2004) [10] who found that fertigation with water soluble fertilizers increased the ascorbic acid content in tomato fruits. Similar trend of result by K fertigation using SOP was reported by Vasu and Reddy (2013) [11] in cabbage. High accumulation of nitrates might be due to higher uptake of nitrogen through fertigation with water soluble fertilizers and this is in agreement with the findings of M'hamdi *et al.*, 2014 [12] in lettuce. Fertigation with water soluble fertilizers increased the total dry matter content which was probably related to increase in the accumulation of calcium. The reason for higher total carotenoids and total antioxidants in the treatment T_2 (fertigation with water soluble fertilizers at 100% RDF) could be that the nutrient application with water soluble fertilizers through fertigation might have increased the availability of nutrients to plants required for growth and quality improvement compared to soil application with straight fertilizers which had leaching and volatilization effect. Chenard *et al.*, 2004 [13] reported that increasing nitrogen dose significantly increased the total carotenoid content in parsley leaves. Similar results were obtained by Kopsell *et al.*, (2007) [14] in kale. Higher content of total antioxidants was observed by Lopez *et al*., 2009 [15] when urea was applied through fertigation in lettuce.

Highest physiological loss in weight of head was recorded in T_1 (soil application with straight fertilizers at 100 per cent RDF) with mean value of 9.18 per cent. And lowest value of physiological weight loss (2.72 per cent) was observed in T_2 (fertigation with water soluble fertilizers at 100% RDF) (Table 2). Continuous uptake of potassium nutrients throught the crop cycle with fertigation might be the possible reason for reduction in physiological weight loss. Optimum level of potassium might have helped in greater translocation of metabolites to storage organs and enhanced thickening of leaves. Thus efficient metabolism and better source sink relationship might have contributed reduction in weight loss in lettuce heads. This result is closely related to findings of Javaria *et al.*, 2012 [16] who observed low physiological loss in weight by increasing the potassium dose in tomato.

In the present study higher mean chrome 'a' value (-15.08) was observed in T_2 (fertigation with water soluble fertilizers at 100% RDF) (Table 1). Total phenols and total antioxidants are said to be responsible for colour induction in many of the vegetable crops. Fertigation with water soluble fertilizers at 100% RDF (T_2) had increased levels of total phenol and total antioxidant content in lettuce heads. So this might also be the

probable reason for high chrome 'a' values in lettuce heads. Similar result was reported by Somawathi *et al.*, 2014 [17] in brinjal.

Table 1: Effect of fertigation on yield characters of lettuce hybrid 'Raider'

Treatments	Head weight (g)	Head diameter (cm)	Yield (t/ha)
T_1	236.22	9.04	11.67
T_2	562.59	14.01	27.83
T_3	524.85	12.42	25.92
T_4	409.94	11.71	20.24
T_5	312.76	10.56	15.44
T_6	553.96	13.13	27.31
T_7	443.60	12.00	21.91
T_8	400.00	11.09	19.76
SE	8.16	0.1693	0.3264
CD (5%)	16.72	0.3472	0.6691

T_1	Soil application with Straight fertilizers at 100% RDF (Control)
T_2	Fertigation with Water soluble Fertilizers at 100% RDF
T_3	Fertigation with Water soluble Fertilizers at 75% RDF
T_4	Fertigation with Water soluble Fertilizers at 50% RDF
T_5	Fertigation with Water soluble Fertilizers at 25% RDF
T_6	Soil application with SF at 25% RDF + Fertigation with Water Soluble Fertilizers at 75% RDF
T_7	Soil application with SF at 50% RDF + Fertigation with Water Soluble Fertilizers at 50% RDF
T_8	Soil application with SF at 75% RDF + Fertigation with Water Soluble Fertilizers at 25% RDF

Table 2: Effect of fertigation on quality characters of lettuce hybrid 'Raider'

Treatments	Ascorbic acid (mg 100 g^{-1})	Nitrate (mg kg^{-1})	Calcium (mg 100 g^{-1})	Total carotenoid (mg g^{-1})	Total antioxidant (µ mol AA g^{-1})	Physiological loss in weight (%)	Colour of head
T_1	37.51	2389.60	10.72	0.13	3.32	9.18	-9.45
T_2	58.05	2439.56	16.09	0.40	4.12	2.72	-15.08
T_3	38.69	2367.10	13.92	0.35	3.75	3.64	-13.96
T_4	40.76	2289.40	12.77	0.30	3.62	3.94	-12.62
T_5	33.75	1981.27	11.55	0.18	3.37	8.22	-11.83
T_6	55.04	2381.24	15.10	0.38	3.96	2.84	-14.45
T_7	43.34	2311.80	13.12	0.31	3.65	3.69	-13.59
T_8	38.96	2317.21	11.69	0.28	3.31	4.14	-12.74
SE	0.609	34.957	0.1696	0.0051	0.0649	0.0771	0.2296
CD (5%)	1.251	71.662	0.3477	0.0104	0.133	0.1581	0.4706

T_1	Soil application with Straight fertilizers at 100% RDF (Control)
T_2	Fertigation with Water soluble Fertilizers at 100% RDF
T_3	Fertigation with Water soluble Fertilizers at 75% RDF
T_4	Fertigation with Water soluble Fertilizers at 50% RDF
T_5	Fertigation with Water soluble Fertilizers at 25% RDF
T_6	Soil application with SF at 25% RDF + Fertigation with Water Soluble Fertilizers at 75% RDF
T_7	Soil application with SF at 50% RDF + Fertigation with Water Soluble Fertilizers at 50% RDF
T_8	Soil application with SF at 75% RDF + Fertigation with Water Soluble Fertilizers at 25% RDF

Conclusion

In this study lettuce grown under fertigation with water soluble fertilizers at 100% RDF improved the yield and quality parameters such as head weight, head diameter, yield, ascorbic acid content, total antioxidants, and calcium content. The physiological loss in weight of head was found be low in fertigation with water soluble fertilizers treatment compared to soil application with straight fertilizers, and fertigation also improved the greenness of the lettuce leaf which contributes the visual quality of the crop.

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