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Influence of various irrigation systems on the growth and yield of Lettuce (*Lactuca sativa* L.)

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Abstract Lettuce being dependent to water during its growth and development is very sensitive to water stress. Lettuce applied with drip irrigation produced the highest crown size (polar, equatorial), most number of leaves and highest yield of 23.42 and 24.33 t ha^{-1} for two cropping periods, respectively. There was no notable effect observed among the various irrigation type on disease incidence. Leafy-type lettuce achieved the maximum plant stand with 89.70% during the second cropping. Head-type obtained the highest marketable yield during the first cropping season of 23.61 t ha^{-1} but leafy-type exhibited the highest yield of 17.72 t ha^{-1} on second cropping. Relatively, leafy-type produced more marketable number of leaves. Drip irrigation improved lettuce yields but there was no consistent varietal effect. Therefore, drip irrigation could possibly enhance lettuce production as implied by its significant effects on the yield and yield components.

Keywords: Crown size, Drip irrigation system, ‘Iceberg’ variety, Lettuce marketability and ‘Romaine’ variety

Introduction

Lettuce (*Lactuca sativa* L.) is an important leafy vegetable crop considered as an excellent nutritive source of minerals and vitamins since it is consumed as fresh green salad (Abu-Rayyan *et al.*, 2004). It is the most popular vegetable with the highest consumption rate and greatest economic importance internationally (Coelho *et al.*, 2005). Vegetables such as letttuce is considered a high-valued crop and are known generally to be very shallow-rooted (Dasberg and Or, 1999) and is dependent on water at all developmental stages, both for germination and in maintaining high photosynthetic rates which serves an important factor in maintaing optimal growth for lettuce (Kirnak *et al.*, 2016) and a fresh biomass of high commercial value (Sanchez, 2000; Nissen and San Mart ń, 2004). Being shallow-rooted and sensitive to water stress, low water

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use efficiency could occur when the roots would unable to utilize deep water in the profile which is an implication that water application does not successfully correspond according to crops' demand (Ahmed *et al.,* 2000 and Kirnak *et al.,* 2016). Thus sufficient and frequent supply of irrigation is needed to avoid possible occurence of water stress as water stress could severely limit crop growth (Kizil *et al.,* 2012).

Irrigated agriculture will face significant challenges in the future as increased food production will depend largely on irrigation and water efficiency (Najafi and Tabatabaei, 2007). Responses of crops to different rates of applied water have been used to determine irrigation strategies for optimal yield and maximum efficiency of water use (Bauder *et al.,* 1975) such that sufficient and balanced water and nutrient application are one of the most important methodologies in obtaining the maximum yield per unit area. According to Tan, (1995); Thompson and Doerge, (1996a-1996b) drip irrigation has many advantages over other types of irrigation and it is the most effective way to supply water and nutrients to the plant which does not only save water but also increases yield of fruit and vegetable crops. Other potential major benefits of drip irrigation include reduced water applications, reduced fertilizer applications, and reduced tillage costs. Scheduling water application is very critical to make the most efficient use of a drip irrigation system, as excessive irrigation reduces yield while inadequate irrigation causes water stress and reduces production (Bozkurt and Bozkurt, 2011). Drip irrigation observed to be most suitable for vegetable growing since it does not interfere with harvesting operations proved to be efficient in water conservation resulting to improved water and fertilizer use efficiencies (Ayars *et al.,* 2015; Jha *et al.,* 2019) as fertilizers can be supplied through the system, foliage is not wetted, and water can be supplied frequently and accurately. In addition, Fang *et al.* (2018) reported that increasing irrigation frequency with drip irrigation maintain higher soil water content in the top soil layers and improved crop water use and yield. Moreover, drip irrigation generally facilitates higher and better quality crop yields, uniform soil moisture distribution in the root zone continuously at an optimum level, effective fertilizer introduction into the root zone and increases the effectiveness of some agricultural inputs like fertilizer (Acar *et al.,* 2008).

Sanchez (2000) demonstrated that yield of lettuce increased in response to water and nitrogen. Overhead irrigation method were reported to be wasteful of water and nutrients (Ahmed *et al.,* 2000) but the abovementioned author found overhead irrigated lettuce seedlings to have a higher dry weight and more leaves while subirrigated lettuce seedlings were significantly taller. Therefore, the provision of constant water supply could reduced the development of water stress and consequently promote growth and increase in production. One option for improving irrigation is to consider other irrigation methods to be integrated in local farming system practices and management.

In Claveria, Misamis Oriental – manual irrigation is the most common and usual method used by the majority of local farmers in supplying water on their crops. Although there are new and more innovative techniques and equipment to supply irrigation to plants, local growers still cling onto this traditional method of irrigation. Also, with the common public perception that drip irrigation installation found to be costly and not widely introduced throughout the locality leaves local vegetable growers discouraged in trying new irrigation techniques and methods such as drip irrigation. This study was done to evaluate and distinguish the growth and yield performance and disease severity and occurrence between leafy-type and head-type lettuce subjected to different irrigation (manual, overhead and drip) systems.

Materials and methods

Site details

The study was conducted at the Agriculture Experiment Station of the University of Science and Technology of Southern Philippines – Claveria Campus, Claveria, Misamis Oriental (SE 8º36.667‘n124º52.964’E) with an elevation of 590 m above sea level. Two protected structures were used for the experiment and each structure measured 6m wide x 47m long, with heat resistant plastic film covering rigid pipes.

Treatments

The experiment consisted of two cropping seasons arranged in a Split-plot Randomized Complete Block Design (RCBD) replicated three times. The main plot consisted of three types of irrigation system (A1 – Manual irrigation, A2 – Drip irrigation, and A3 – Overhead irrigation) and subplot was the two varieties (B1 – Leafy-type and B2 – Head-type).

Cultural management practices

A sterilized soil mixture of garden soil, vermicast, lime and sand with a ratio of 4:5:½:1 on a seedling tray was the planting medium for the lettuce seedlings. Seedlings were raised in an enclosed nursery prior to transplanting. Each treatment plot had an area of 1m x 5m. Seedlings were transplanted four to five weeks after sowing with planting distance of 0.3m x 0.3m. The study used the Romaine variety (1^{st} cropping) and Xanadu (2^{nd} cropping) for Leafy-type and Iceberg variety for Head-type during both cropping season. Basal application of bio-organic fertilizer (1.1 - 2.83 - 1.61 of N-P_2O_5-K_2O with 5.78% Ca and some amount of trace elements e.g. 0.87% Fe, 0.019% Cu, 8.312 ppm Mg, 927 ppm Mn, and 339 ppm Zn) at a rate of 10g was applied to plants during the first cropping while 10g Vermicast was applied on second cropping. Installation of drip and overhead irrigation followed after transplanting. The first protected structure was subjected to manual and drip irrigation while the overhead got a separate section in another protected structure to facilitate ease management of watering within plots. For the drip irrigation, one drip in every row was established in all experimental plots. Scheduling of water irrigation was done two hours (7am-9am) regularly every morning. Harvesting of head-type variety was done when the head was full and compact at about 30 days after transplanting. On the other hand, leafy-type variety was harvested when the leaves reached it's full size having dark green in color and are overlapped in a tight bunch at around 45 days after transplanting.

Data collection and analysis

The following parameters were gathered: plant stand, crown size (polar and equatorial length), number of marketable and non-marketable leaves and yield in tons per hectare. Disease assessment was done by recording the number of plants infested of randomly selected sample plants; the incidence of diseases was monitored and rated every three days interval using the following criteria below (NVTWG-PSB, 1985).

Rating Scale	Description
1	No infestation/infection. (None of the total plant population is infested/infected)
2	Mild infestation/infection. (1-25% of the total plant population are infested/infected)
3	Moderate infestation/infection (26-50% of the total plant population are infested/infected)
4	Severe infestation/infection (51-75% of the total plant population are infested/infected)
5	Very severe infestation (76-100% of the total plant population are infested/infected)

The obtained data were subjected to analysis of variance (ANOVA) using ASSISTAT (version 7.0 beta). The Tukey test was used to determine the significant differences among treatments means at 5% ($P<0.05$) level of significance.

Results

Plant stand

Significant differences were only found between the two cultivars during the second cropping (Table 1) with leafy-type having the higher plant stand of 89.70% compared to the head-type with only 78.18%. Different irrigation techniques did not affect the plant stand of lettuce for both cropping period.

Table 1. Plant stand of lettuce as influence by different types of irrigation system between varieties during two cropping systems

Treatments		Plant stand (%)	
		1st Cropping	2nd Cropping
Types of Irrigation (A)			
Manual		96.29	84.55
Drip		95.03	84.55
Overhead		95.03	82.70
	F-test	ns	ns
Varieties (B)			
Leafy – Type		93.81	89.70a
Head – Type		97.11	78.18b
	F-test	ns	*
A x B			
	F-test	ns	ns
CV (%)			
(A)		3.99	3.75
(B)		4.43	4.99

* Significant at a level of 5% of probability (.01 =< p < .05)
ns = Not-significant (p >= .05)

Yield and yield components

Crown size

The crown size exhibited a significant interaction between the varieties and type of irrigation system (Table 2). Throughout the cropping season, leafy-type and drip irrigation individually recorded bigger crown size for both first and second cropping. Head-type lettuce applied with overhead irrigation measured the smallest crown size in both polar and equatorial measurements regardless of cropping season.

Table 2. Crown size and number of leaves as influenced by different irrigation systems for two cropping period

Treatments	1st Cropping				2nd Cropping			
	Crown size (cm)		Number of leaves		Crown size (cm)		Number of leaves	
	Polar	Equatorial	Marketable	Non-marketable	Polar	Equatorial	Marketable	Non-marketable
Types of Irrigation (A)								
Manual	22.66a	19.83a	21.33b	11.66a	15.83b	13.00b	16.50b	14.83b
Drip	23.66a	19.83a	23.16a	12.83a	21.83a	15.50a	17.33a	16.16a
Overhead	17.50b	15.16b	13.00c	6.33b	15.83b	11.50b	11.17c	9.41c
F-test	**	**	**	**	**	**	**	**
Varieties (B)								
Leafy – Type	32.77a	25.77a	20.00a	11.11	27.44a	17.44a	15.44	14.17a
Head – Type	9.77b	10.77b	18.33b	9.44	8.22b	9.22b	14.56	12.77b
F-test	**	**	*	ns	**	**	*	*
A x B								
F-test	**	**	ns	**	**	**	ns	ns
CV (%)								
(A)	5.08	2.23	2.13	10.51	4.77	3.54	5.67	2.31
(B)	3.67	3.65	3.98	8.11	5.91	10.00	2.94	4.37

Number of leaves

As presented on Table 2, lettuce grown under drip irrigation was consistent to the most number of marketable leaves per plant during both cropping periods. Although overhead irrigation produced the least number of non-marketable leaves for all growing periods, it also reported the least number of marketable leaves among the irrigation systems. Among varieties, head-type lettuce obtained the lowest number of non-marketable leaves during the second cropping season.

Yield

Drip irrigation consistently resulted in the highest marketable yield of 234.16g (first cropping) and 243.66g (second cropping). Head-type lettuce produced the highest marketable yield of 236.11g during the first cropping which translated into a yield per hectare of 23.61t ha^{-1} (Table 3). However, leafy-type lettuce performed better in the second cropping producing the highest marketable yield (176.33g) in which translated into a yield per hectare of 17.72t ha^{-1}

Table 3. Effect of different irrigation system on the yield performance of lettuce between varieties during two cropping systems

Treatments	1st Cropping			2nd Cropping		
	Yield (g $plant^{-1}$)		Yield (t ha^{-1})	Yield (g $plant^{-1}$)		Yield (t ha^{-1})
	Marketable	Non-marketable		Marketable	Non-marketable	
Types of Irrigation (A)						
Manual	227.33b	119.33b	22.73b	111.16b	97.50b	11.16b
Drip	234.16a	204.83a	23.42a	243.66a	234.16a	24.33a
Overhead	217.00c	105.66c	21.70c	119.33b	104.16b	11.25b
F-test	**	**	**	**	**	**
Varieties (B)						
Leafy – Type	216.22b	78.77b	21.62b	176.33a	163.33a	17.72a
Head – Type	236.11a	207.77a	23.61a	134.66b	127.22b	13.44b
F-test	**	**	**	**	**	**
A x B						
F-test	**	**	**	**	**	**
CV (%)						
(A)	1.82	2.33	1.82	4.46	3.54	5.29
(B)	1.14	2.86	1.14	3.92	6.57	4.07

** Significant at a level of 1% of probability ($p < .01$)

Disease incidence

There was no notable difference in disease incidence among the lettuce regardless of the variety and irrigation technique used throughout all growing period (Table 4).

Table 4. Influence of different type of irrigation system in the incidence of diseases between varieties for two cropping systems

Treatments		**Disease Incidence**	
		(1st Cropping)	**(2nd Cropping)**
Types of Irrigation (A)			
Manual		2.66	2.83
Drip		2.16	2.50
Overhead		2.83	3.16
	F-test	ns	ns
Varieties (B)			
Leafy – Type		2.44	2.77
Head – Type		2.66	2.88
	F-test	ns	ns
A x B			
	F-test	ns	ns
CV (%)			
(A)		13.18	11.98
(B)		8.89	7.91

Disease Incidence Rating: 0 = none of the total population; 1 = 1-25 % of the population; 2 = 26-50 % of the population; 3 = 51-75 % of the population; 4 = 76-100 % of the population
ns = Not-significant (p >= .05)

Discussion

Drip irrigation is considered to have many advantages over other types of irrigation (Tan, 1995; Thompson and Doerge, 1996a-1996b) affirming the results – bigger crown size, highest yield per plant and per hectare, and gained most number of leaves for both first and second cropping period. Sanchez (2000) demonstrated similar increase in yield in response to water and nitrogen. Therefore, the provision of constant water supply could reduced the possiblity of water stress occurence as lettuce is known to be very shallow-rooted (Dasberg and Or, 1999) subsequently promoted growth and increase in lettuce production. Moreover, drip irrigation is a more efficient irrigation technique that not only conserves water but also improves water and fertilizer use efficiencies (Ayars *et al.,* 2015; Jha *et al.,* 2019), facilitates uniform soil moisture distribution in the root zone continuously at an optimum level resulting into more effective fertilizer introduction into the root zone (Acar *et al.*, 2008).

Individually, significant variation was observed between cultivars grown by the different irrigation systems. Between varieties, leafy-type recorded to have the highest results for the measured parameters: plant stand, yield per plant and per hectare basis during the second cropping season, crown size and number of leaves for two consecutive cropping periods. On the other hand, head-type got the highest yield per plant (marketable), and yield per hectare during the first cropping season. Drip irrigation showed the optimum result on crown size (polar and equatorial), marketable and non- marketable number of leaves, total yield per plant and yield per hectare. Irrigation did not show any significant effect on disease incidence. Drip irrigation enhance lettuce production as implied by its significant effects on the yield and yield components.

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References

Abu-Rayyan, A., Kharawish, B. H. and Al-Ismail, K. (2004). Nitrate content in lettuce (Lactuca sativa L.) heads in relation to plant spacing, nitrogen form and irrigation level. Journal of the Science of Food and Agriculture, 84:931-936.

Acar, B., Paksoy, M., Türkmen, Ö. and Seymen, M. (2008). Irrigation and nitrogen level affect lettuce yield in greenhouse condition. African Journal of Biotechnology, 7.

Ahmed, A. K., Cresswell, G. C. and Haigh, A. M. (2000). Comparison of sub-irrigation and overhead irrigation of tomato and lettuce seedlings. The Journal of Horticultural Science and Biotechnology, 75:350-354.

Ayars, J. E., Fulton, A. and Taylor, B. (2015). Subsurface drip irrigation in California—Here to stay. Agricultural Water Management, 157:39-47.

Bauder, J. W., Hanks R. J. and James D.W. (1975). Crop Production Function Determinations as Influenced by Irrigation and Nitrogen Fertilization Using a Continuous Variable Design 1. Soil Science Society of America Journal, 39:1187-1192.

Bozkurt, S. and Bozkurt, G. S. (2011). The effects of drip line depths and irrigation levels on yield, quality and water use characteristics of lettuce under greenhouse condition. African Journal of Biotechnology, 10:3370-3379.

Coelho, A. F. S., Gomes, É. P., Sousa, A. D. P and Glória, M. B. A. (2005). Effect of irrigation level on yield and bioactive amine content of American lettuce. Journal of the Science of Food and Agriculture, 85:1026-1032.

Dasberg, S. and Or, D. (1999). Practical applications of drip irrigation. In Drip irrigation (pp. 125-138). Springer, Berlin, Heidelberg.

Fang, Q., Zhang, X., Shao, L., Chen, S. and Sun, H. (2018). Assessing the performance of different irrigation systems on winter wheat under limited water supply. Agricultural Water Management, 196:133-143.

Jha, S. K., Ramatshaba, T. S., Wang, G., Liang, Y., Liu, H., Gao, Y. and Duan, A. (2019). Response of growth, yield and water use efficiency of winter wheat to different irrigation methods and scheduling in North China Plain. Agricultural water management, 217:292-302.

Kirnak, H., Tash, I., Gokalp, Z. and Karaman, S. (2016). Effects of different irrigation levels on yield of lettuce grown in an unheated greenhouse. Current Trends in Natural Sciences, 5:145-151.

Kizil, Ü., Genc, L., Inalpulat, M., Şapolyo, D. and Mirik, M. (2012). Lettuce (*Lactuca sativa* L.) yield prediction under water stress using artificial neural network (ANN) model and vegetation indices. Žemdirbystė= Agriculture, 99:409-418.

Najafı P. and Tabatabaei S. H. (2007). Effect of using subsurface drip irrigation and Et-Hs model to increase wue in irrigation of some crops. Irrigation and Drainage, 56:477-486.

Nissen, J., and K. San Mart ń. (2004). Uso de poliacrilamidas y el riego en el manejo h ídrico delechugas (Lactuca sativa L.). Agro Sur, 32:1-12.

Sanchez, C. H. A. (2000). Response of lettuce to water and nitrogen on sand and the potential for leaching of nitrate-N. HortScience, 35:73-75.

Tan, C. S. (1995). Effect of drip and sprinkle irrigation on yield and quality of five tomato cultivars in Soutwestern Ontario. Canadian Journal of Plant Science, 75:225-230.

Thompson, T. L. and Doerge, T. A. (1996a). Nitrogen and water interactions in subsurface trickle-irrigated leaf lettuce. I: Plant response. Soil Science Society of America Journal, 60:163-168.

Thompson, T. L. and Doerge, T. A. (1996b). Nitrogen and water interactions in subsurface Trickle- irrigated leaf lettuce. II: Agronomic, economic, and environmental Outcomes. Soil Science Society of America Journal, 60:168-173.

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