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Effects of Furrow Height and Amount of Manure Compost on the Growth, Yield, and Quality of Organically Grown Green Asparagus

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Abstract

A two-season field trial was carried out in the Upland Crop Experiment Field of the Faculty of Agronomy, Vietnam National University of Agriculture (VNUA) to assess the effects of three furrow heights (20, 35, and 50cm) and three manure compost levels (15, 25, and 35 tons ha^{-1}) on the growth, yield, and quality of green asparagus (*Asparagus officinalis* L.) grown organically. The experiments were arranged in a randomized completely block design (RCBD) with three replications. The results showed that the harvested yield was highest (11.3 and 25.1 quintals ha^{-1} in the 2019 autumn and 2020 spring season, respectively) in the treatment with a furrow height of 35cm and compost level of 35 tons ha^{-1} in both seasons, and explained by the increased spear diameters and number of spears per plant in this treatment when the furrow height and compost level were increased. Additionally, the chlorophyll content, water loss, and dry matter weight of the spears also increased when the furrow height and compost level increased. The obtained quality of the spears under organic management at the furrow height of 35 cm and compost level of 35 tons ha^{-1} was higher than the other treatments with higher reducing sugars, vitamin C, and Brix values, while the residue nitrate contents of all the treatments were lower than the allowed safety threshold.

Keywords

Compost level, furrow height, green asparagus, yield and quality of spears

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Introduction

Asparagus (*Asparagus officinalis* L.) is a perennial crop and a nutritious vegetable that is good for human health because it is rich in minerals, vitamins, amino acids, and fiber (Hamdi *et al.*, 2018). In addition, asparagus is also rich in antioxidant compounds

such as phenols, carotene oligosacharides, and rutin. In recent years, human interest in functional foods biosynthesized from plants has been increasing, so the demand for asparagus for consumption has also tended to increase. In particular, green asparagus, a variety mainly grown in tropical countries, contains large amounts of rutin (Maeda *et al.*, 2012; Motoki *et al.*, 2012), one of the main flavonoids with biological and pharmacological activities such as anti-inflammatory, anti-cancer, and anti-bacterial as well as provides effective protection against atherosclerosis (Guo *et al.*, 2002; Calabro *et al.*, 2005). The vitamin A content of green asparagus is higher than that of white asparagus (Hussain *et al.*, 2006).

Organic farming is currently a very promising production method because it not only produces high-quality products but also contributes to improving the health of soil, ecosystems, and humans (IFOAM, 2005). Additionally, organic agriculture does not use chemical inputs as it is based on biological cycles, biodiversity, and cycles adapted to local conditions (IFOAM, 2005). In organic farming, the role of composting manure is essential, because it not only maintains soil organic carbon matter but also improves the chemical and physical properties of the soil (Hirzel et al., 2018). Several studies have shown that the benefits of compost supplementation include improved soil chemical properties, buffering capacity, cation exchange capacity (CEC), soil fertility, supply nutrition levels, especially N, P, K, Ca, and Fe (Bruun *et al.*, 2006), and biological properties (Garcia-Gil *et al.*, 2000).

The yield of asparagus not only depends on the external conditions, cultivation practices, or harvesting methods and dates, but also on internal factors determined by specific genetic characters of the grown cultivars or the age of the plants (Gasecka *et al.*, 2008) and storage carbohydrates in the crown (Wilson *et al.*, 2008). In Vietnam, asparagus is a fairly new crop so research about cultivation techniques is needed, especially for organic farming purposes. In organic asparagus cultivation, the furrow height and manure compost applications are two important factors. On the one hand, the furrow height or the depth of soil bed influences spear weight and yield (Loughton, 1996), and the spear weight has been shown to increase with the depth (Takatori *et al.*, 1974). On the other hand, the nutrient requirements of asparagus are fairly high with 200kg N, 60kg P_2O_5, and 120kg K_2O_5 ha^{-1} annually (Hikasa, 2000), so the question is how much manure compost is enough for asparagus grown in an organic system. With the increasing demand for organically grown asparagus in Vietnam, our research aimed to determine a suitable furrow height and manure compost amount for green asparagus grown by seedlings in order to improve the yield and quality of asparagus, and fulfill the organic asparagus production techniques for asparagus growers in Vietnam.

Materials and Methods

Materials

The experiment was conducted in 2019 and we collected data during two harvest seasons: the 2019 autumn season (the asparagus was harvested at 9 months after planting-MAP) and the 2020 spring season (the asparagus was harvested at 12 MAP). The experiment field was located at the Upland Crop Experiment Field of the Faculty of Agronomy, Vietnam National University of Agriculture, Hanoi, Vietnam (altitude ± 20m from the sea level). The soil was alluvial soil with pH (5.6-7.0), OM (2.1%), and N (0.26%). The asparagus variety used was the Sunlim F1 variety belonging to the LimGroup, Netherlands. This variety is well adapted to a temperate, tropical monsoon climate. The shoot weight was about 32g per shoot with a length of 23cm and diameter of 10mm. The shoots were green, from dark to light green with small, purplish scale leaves and bud scales. This variety has an early harvest time, high yield, and good resistance to fungal diseases, fusarium, rust, and other infectious diseases. The asparagus was grown by seedlings in a greenhouse, and 60-day-old asparagus plants were transplanted to the experiment field (in March 2019) in two rows

with a distance of 0.75m between rows and 0.4m between plants.

Chicken manure compost was applied at the beginning of each season. The nutrient content of the manure compost was as follows: OM (20.5%), N (0.92%), P_2O_5 (1.63%), and K_2O (0.81%). Additionally, supplemental organic nutrient sources including fishmeal and soybean meal were applied in the same amounts in each treatment five days per time. The asparagus field was cultivated following the Vietnamese National Standards for Organic Crop Production (TCVN 11041:2-2017).

Experimental Design

The two-factor experiment consisted of nine treatments arranged in a randomized completely block design (RCBD) with three replications and each replication area was $5m^2$. The furrow height (L) consisted of the three height levels 20, 35, and 50cm named L1, L2, and L3, respectively. Three doses of manure compost (P) at the levels of 15, 25, and 35 tons ha^{-1} were applied and named P1, P2, and P3, respectively.

Measurements

The heights and diameters of ten randomly selected spears in each replication were measured after harvesting the spears.

The chlorophyll a and b contents were assessed by the adsorption spectral analysis method following leaf extractions in a 96% ethanol solution. One gram of matured fern leaf tissue (fresh weight at 30 days after spear establishment) was added to a closed falcon tube containing 10mL of ethanol and put in dark conditions within 48 hours to complete the extraction of the chlorophyll solution in the leaves. After that, the solution was measured using a UV-2900 spectrophotometer (Hitachi, Japan). Absorbance (OD) was measured at the wavelengths 665 and 649nm. The chlorophyll a and b contents were calculated according to the following equations by Wintermans & De Mots (1965):

Chlorophyll a = 13.7 x A665 – 5.67 x A649 ($\mu g\ mL^{-1}$),

Chlorophyll b = 25.8 x A649 – 7.60 x A665 ($\mu g\ mL^{-1}$), and

Chlorophyl a+b = 6.1 x A665 + 20.04 x A649 ($\mu g\ mL^{-1}$).

Spear moisture content and moisture retention capacity were determined on a fresh weight basis. For each treatment, ten spears per replication were harvested separately and the fresh weights were recorded immediately. The spears were kept in normal room conditions ($26^oC \pm 1^oC$ temperature, 75% ± 3% relative humidity) for 12, 24, or 36 hours. After 12, 24, and 36 hours, the spears were weighed for calculating spear moisture loss. Then, these spears were dried in the oven at 80^oC for 48 hours until a constant weight was reached and the dry weights were recorded. The spear moisture content (SMC) and spear moisture loss of the treatments were calculated separately using the following formulas and expressed as percentages (%):

$$Spear\ moisture\ content\ (\%) = \frac{(Fresh\ weight\ of\ spear - Dry\ weight\ of\ spear)}{Fresh\ weight\ of\ spear}\ x\ 100$$

and

$$Spear\ moisture\ loss\ (\%) = \frac{(Fresh\ weight\ of\ spear - Weight\ of\ spear*)}{Fresh\ weight\ of\ spear}\ x\ SMC.$$

**weight of spear after 12, 24, and 36 hours after harvesting*

Asparagus spears were harvested during the growth season. The number of spears and weights were recorded at each harvest. The individual and total yield data were recorded.

In order to evaluate some spear quality criteria, 20 random spears were collected in each treatment to measure the Brix values on the spear sap immediately after harvesting using a Brix Milwaukee 882 machine, the reducing sugar content (glucose and fructose) by TCVN 11470: 2016, the vitamin C content by TCVN 8977: 2011, and the content of NO_3^- residue by TCVN 8742: 2011.

Data analysis

Analysis of variance (ANOVA) was performed using Minitab 16 according to RCBD

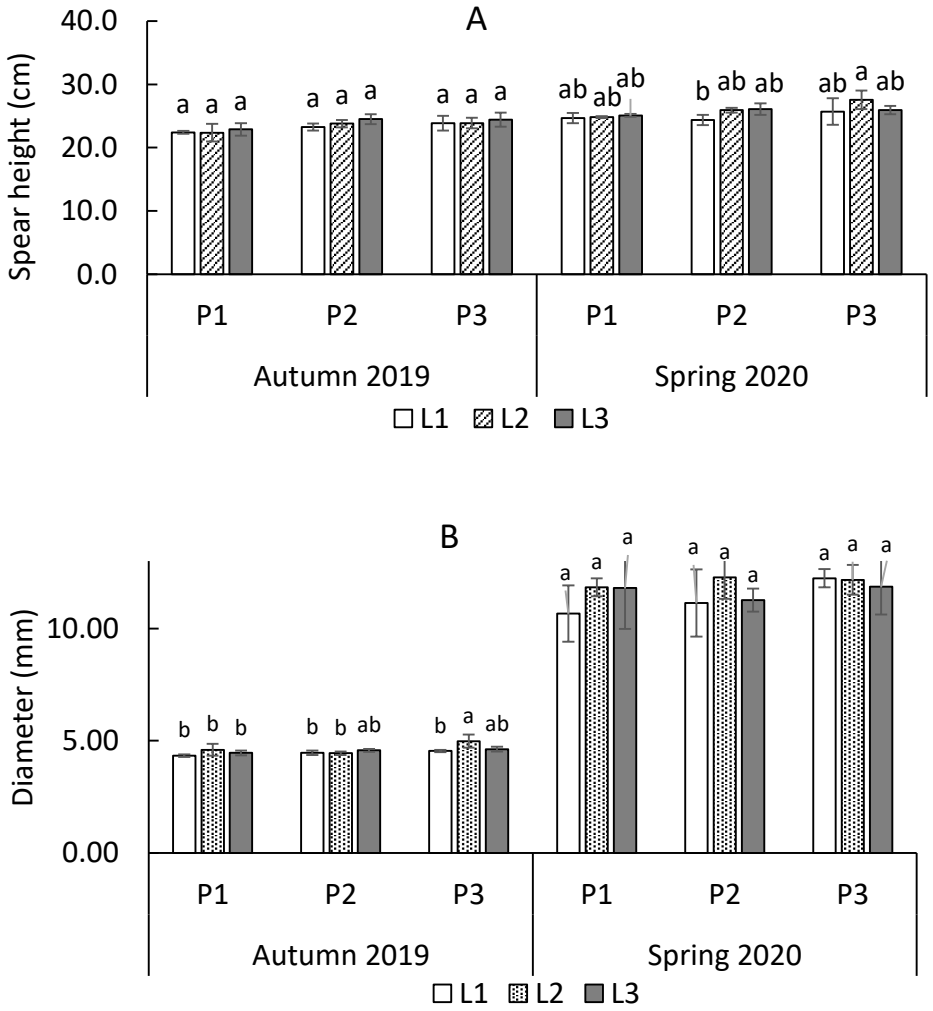
to assess furrow height differences, manure compost levels, and furrow height × manure compost levels interactions. The differences of mean values were analyzed using Tukey's test at $P< 0.05$).

Results and Discussion

Effects of furrow height and manure compost level on the height and diameter of asparagus spears

In the 2019 autumn season, the asparagus spears were harvested after being in the field nine months after transplanting. The increments of manure compost dose and furrow height did not influence the heights of the spears (**Figure 1A**), while in the 35 tons ha^{-1} manure compost treatment (P3), when the furrow height increased from 20cm (L1) to 35cm (L2), the spear diameter significantly increased but when the furrow height increased to 50cm (L3), the diameter did not change (**Figure 1B**).

In the 2020 spring season, at 12 months after transplanting, the heights of the spears were not different from those in the 2019 autumn season but the spear diameters were about 2-3 times wider than those in the 2019 autumn season (**Figure 1**). The increments of manure compost dose and furrow height did not influence the



Note: Values within a season for each column followed by the same lowercase letter are not significantly different at the 0.05 probability level by Tukey's test.

Figure 1. Effects of furrow height (L) and compost level (P) on the height (A) and diameter (B) of asparagus spears

heights of spears in the spring season, while the increase of furrow height from 20cm (L1) to 35cm (L2) significantly increased the spear diameters but then the diameters reduced slightly when the furrow height increased to 50cm (L3) (**Figure 1B**).

Effects of furrow height and manure compost level on the physiological characteristics of green asparagus

Chlorophyll content (µg mL^{-1})

In the analysis of furrow height on chlorophyll a content, the plants in the 50cm deep (L3) bed had significantly higher chlorophyll a levels compared to the two other furrow height levels L1 (20cm) and L2 (35cm). Increases in the manure compost dose and furrow height increased the content of chlorophyll b, while the chlorophyll a+b content was unchanged when the manure compost dose and furrow height were increased (**Figure 2**).

Water loss after harvest (%)

Water loss reflects a plant's ability to maintain the freshness of the product after harvest. This depends on the cultivation method, weather conditions, product characteristics, and storage methods. Under the same weather conditions and methods of preservation, the natural water loss of the spears showed that the water loss after 12, 24, and 36 hours increased gradually with the largest value 36 hours after harvest (**Figure 3**). Since weight loss was lower than 6% in the asparagus spears, storage can be considered acceptable for the market (An *et al.*, 2004). The weight loss of asparagus spears during storage is mainly due to moisture loss, and storage temperature and relative humidity have a significant effect on weight loss. The experiment showed that to keep asparagus fresh it is necessary to store the product in a controlled environment.

Dry weight of asparagus spears (g)

The dry matter of the asparagus spears in the 2019 autumn season was higher than in the 2020 spring season possibly due to the spears in the 2019 autumn season being small with a thick cover so the fiber content was high. This can be explained by the observation that in the summer-autumn season the spear fiber increased caused by caliber reduction which prevailed over the opposite effect of temperature as reported by Caruso *et al.* (2012). In the 2020 spring season with the rapid growth of the spears (only a 3 day time frame for harvesting compared to 4 days in the 2019 autumn season) together with a strong increase of spear diameters, the water content of the spears increased and the dry matter content was low. The two treatments L2P3 and L3P2 had the highest dry matter weights of 8.1g and 8.0g per 100g of fresh weight, respectively, in the 2019 autumn season, while L2P2 had the highest dry matter weight of 5.2g per 100g fresh weight in the 2020 spring season (**Figure 4**).

Effects of furrow height and compost level on the yield and yield components of green asparagus

Number of spears plant^{-1}

When the furrow height increased, the average number of spears per plant increased, reaching the highest value at the furrow height of 50cm (L3). Similarly, the compost level of 35 tons ha^{-1} (P3) gave the highest number of spears, which was significantly different from the other two compost levels. The treatments L3P2, L3P3, and L3P1 had the highest average numbers of spears per plant at 9.7, 9.5, and 9.1 spears, respectively, in the 2019 autumn season (**Figure 5**).

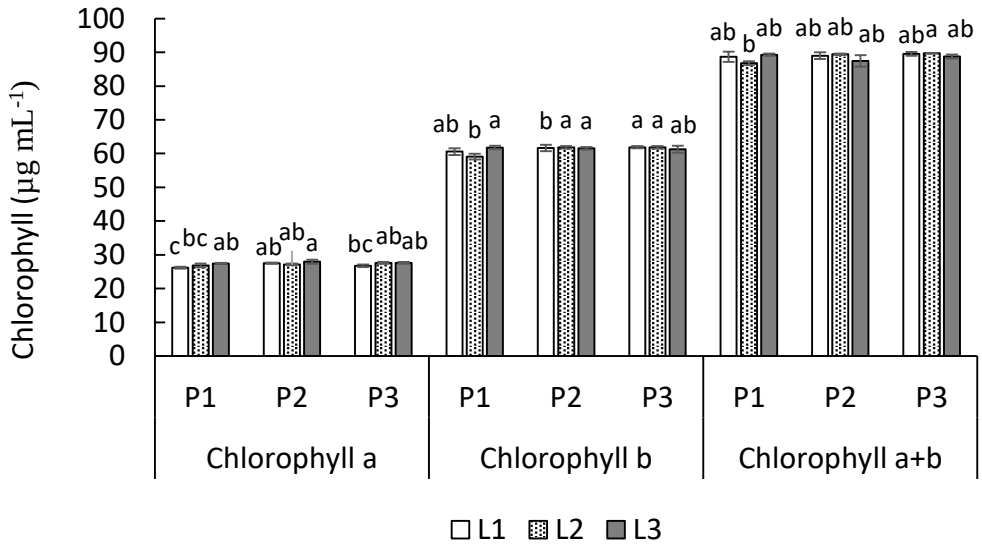
In the 2020 spring season, the P3 level of manure compost (35 tons ha^{-1}) still gave the highest number of spears per plant, but the furrow height of 35cm (L2) had the highest number of spears and the difference was significantly higher compared to the remaining two levels. The L2P3 treatment gave the highest number of spears of 9.2, significantly higher compared to the other treatments, in the spring season of 2020 (**Figure 5**).

These results might be due to the fact that a high compost level and furrow height increased the uptake of moisture and nutrients which resulted in increased vegetative growth and provided balanced nutrition and an excellent environment for the root system of the plant, and

as a result, higher numbers of spears per plant were obtained at this compost level (Hussain *et al.*, 2006).

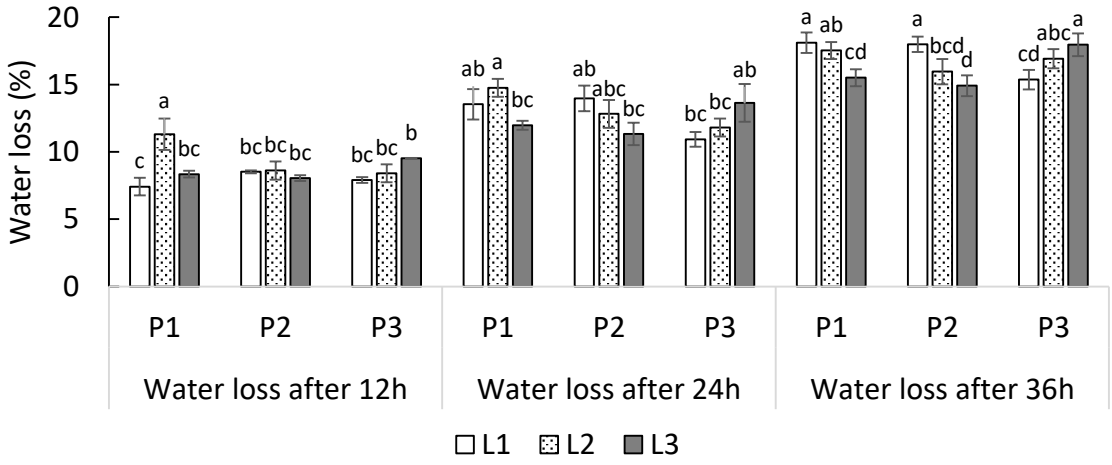
Spear weight (g)

Furrow height, compost level, and their interaction significantly affected spear weight in both seasons (**Figure 6**). In the 2019 autumn season, there were no significant differences in spear weight as the level of compost increased up to 35 tons ha^{-1}. The highest spear weight (15.8g) was produced by the plants supplied with 35 tons ha^{-1} and the lowest weight (15.4g) was recorded in plants that received the compost level of



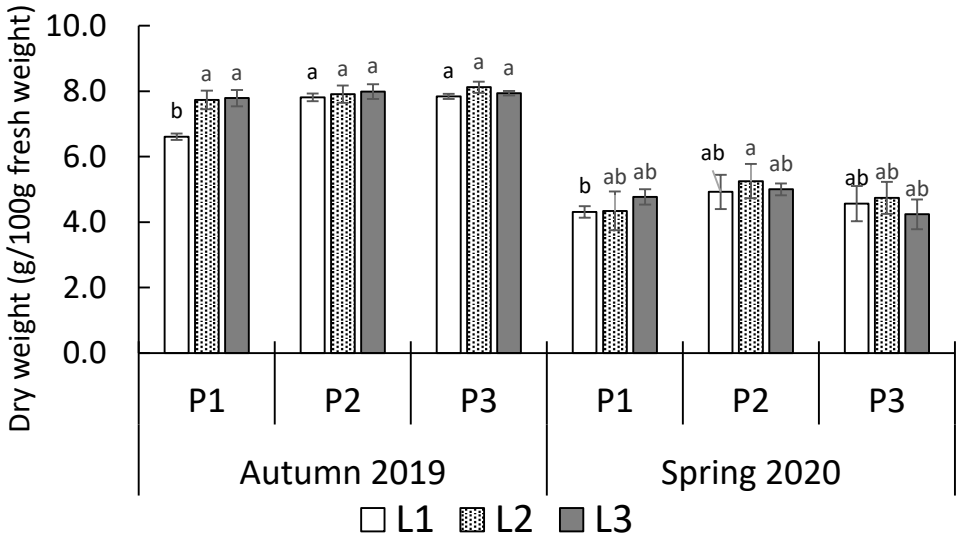
Note: Values within a stage for each treatment followed by the same lowercase letter are not significantly different at the 0.05 probability level by Tukey's test.

Figure 2. Effects of furrow height (L) and manure compost level (P) on the chlorophyll a, b, and a+b content of green asparagus



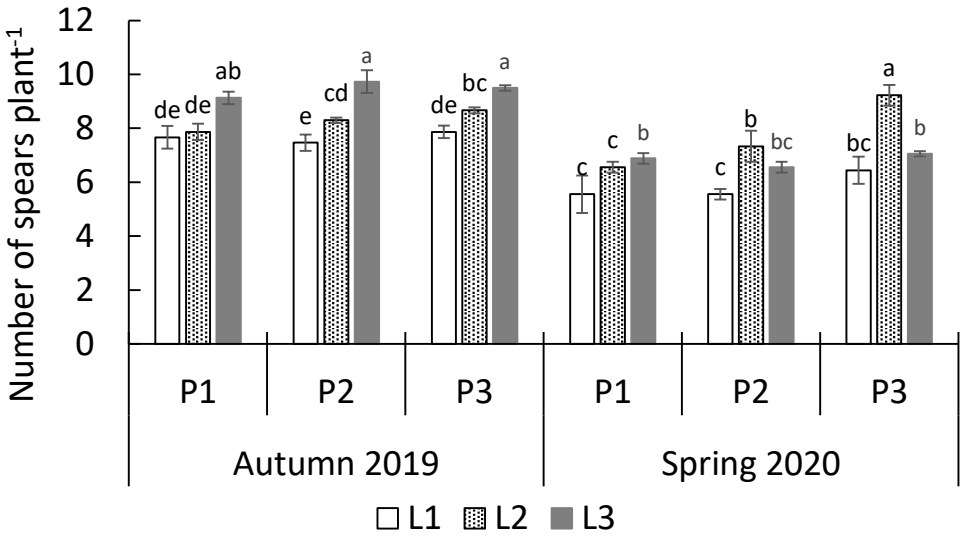
Note: Values within a stage for each treatment followed by the same lowercase letter are not significantly different at the 0.05 probability level by Tukey's test.

Figure 3. Effects of furrow height (L) and manure compost level (P) on water loss after 12, 24, and 36 hours after harvest of asparagus spears



Note: Values within a stage for each treatment followed by the same lowercase letter are not significantly different at the 0.05 probability level by Tukey's test.

Figure 4. Effects of furrow height (L) and manure compost level (P) on the dry weight of asparagus spears



Note: Values within a stage for each treatment followed by the same lowercase letter are not significantly different at the 0.05 probability level by Tukey's test.

Figure 5. Effects of furrow height (L) and manure compost level (P) on the average number of asparagus spears per plant

15 tons ha^{-1}. The furrow heights of 50cm (L3) and 35cm (L2) were not statistically different for average spear weight.

In the 2019 autumn season, the L2P3 treatment gave the highest average spear weight of 16.0g $plant^{-1}$. Whereas in the 2020 spring season, at 12 months after transplanting, the spear weights increased significantly compared to those in the 2019 autumn season due to the sharp increases in spear diameter (**Figure 1B**). The P3 compost level with 35 tons ha^{-1} had the largest spear weight with

19.6g, but was not significantly different from the P2 level (19g). The treatment L2P3 again gave the highest average spear weight of 20.1g.

Yield ha^{-1}

The data recorded on yield ha^{-1} (quintals) were significantly affected by compost level, furrow height, and the interaction of the two factors (**Figure 7**). In the 2019 autumn season, in terms of compost level, yield increased when the compost level increased up to 35 tons ha^{-1} but was not significantly different from the compost level of 25 tons ha^{-1}. The highest yield (10.5 quintals ha^{-1}) was recorded in the compost level of 35 tons ha^{-1}. In the 2020 spring season, the highest yield (22.2 quintals ha^{-1}) was also recorded with the compost level of 35 tons ha^{-1}, but was not significantly different from the 25 tons ha^{-1} compost level. Several studies on nutrients for asparagus showed that the optimum dose of nitrogen increased yield (Hussain *et al*., 2006) due to more vegetative growth of the aerial plant parts and a good environment for the root system, resulting in maximum spear weights and higher numbers of spears (Sanders & Benson, 1999; Hussain *et al.,* 2006). At lower than optimum doses, the nutrients were not sufficient for the plants, which led to suppressed growth, and thus, reduced yield (Hussain *et al.,* 2006), but higher doses of nitrogen also decreased yield by suppressing the fertilizer uptake efficiency of the plants (Haynes *et al.,* 1986). Our experiments observed that the higher the dose of applied manure compost (in our studies' range), the higher the achieved spear yield, and the optimum dose of manure compost was 35 tons ha^{-1}.

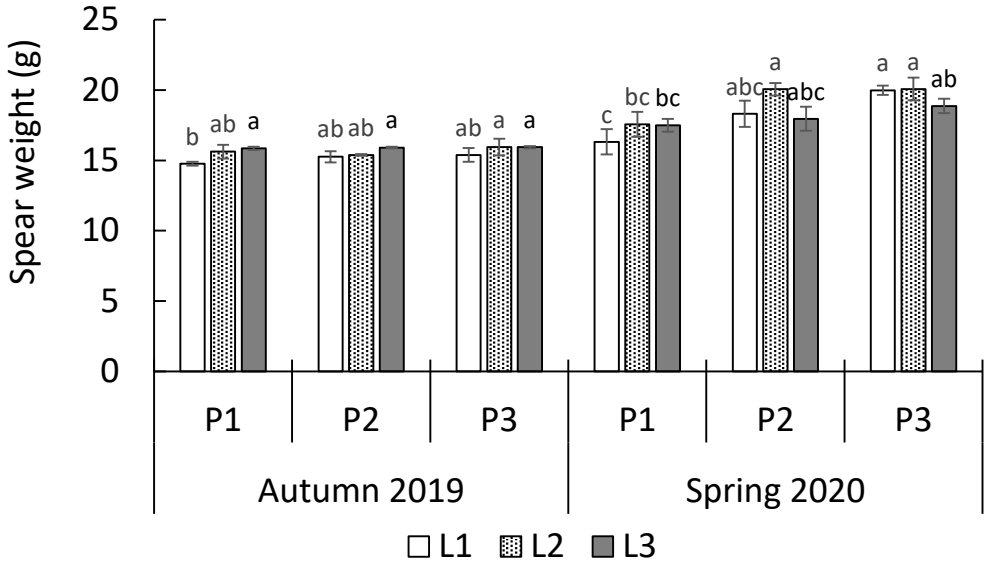
In terms of furrow height, the highest yields (10.6 and 22.5 quintals ha^{-1}) were observed in the 35cm furrow height treatment and lowest yields (10.3 and 19.2 quintals ha^{-1}) in the 20cm furrow height treatment in the 2019 autumn and 2020 spring seasons, respectively. Lindgren (1990) showed that increasing the growth depth significantly delayed spear emergence. Total yield tended to increase at a shallower depth but this was not consistently significant. The average spear weight was significantly greater with deeper plantings. In our experiments, the average spear weight increased significantly when the growth depth increased from 20cm to 35cm but decreased when the growth depth continued to increase to 50cm. Similar results were observed in spear yields in both harvest seasons. Therefore, the L2P3 treatment (35cm furrow height with a 35-ton ha^{-1} manure compost application) had the highest number of spears per plant and average spear weight in the 2020 spring harvest season and then achieved the highest yield. A similar report by Takatori *et al.* (1974) showed that the spear weight and yield increased with the planting depth (**Figure 7**).

With regard to the interaction between the two variables, the highest yield (11.3 quintals ha^{-1}) was recorded in the 35cm (L2) furrow height treatment supplied with 35 tons compost ha^{-1} (P3), but no significant differences were observed among the L3P3, L2P3, and L2P2 treatments in the 2019 autumn season. In the 2020 spring season, the highest yield (25.1 tons ha^{-1}) was obtained in the 35cm furrow height (L2) treatment combined with the 35 tons ha^{-1} manure compost application (P3). This treatment had the highest number of spears per plant and average spear weight in this season (**Figure 5 and Figure 6**).

Effects of furrow height and compost level on the quality of green asparagus

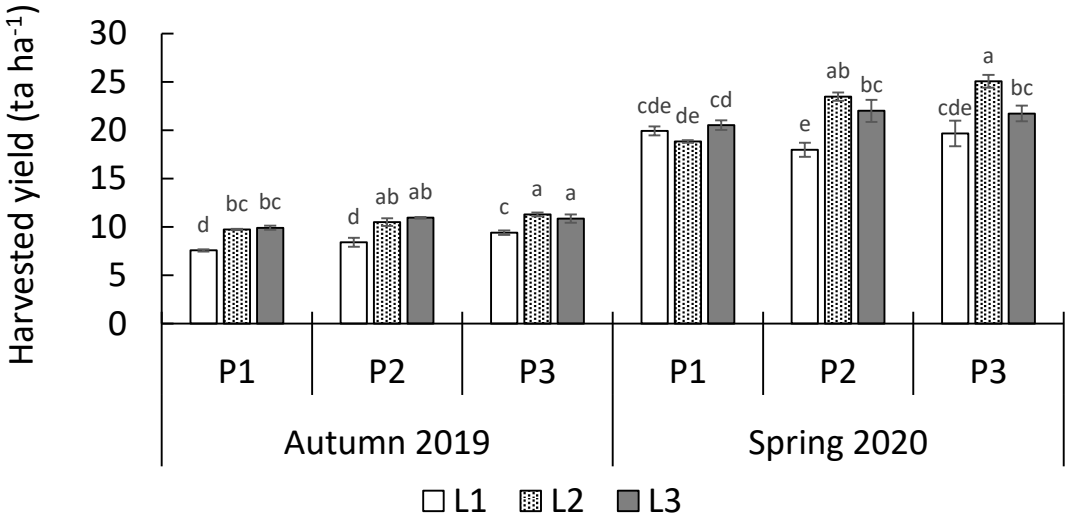
With regard to the quality indicators (**Table 1**), there were significant differences in quality between the two seasons, as the autumn season spears showed higher values of reducing sugars, vitamin C, and Brix readings than the spring ones, and the results were consistent with those reported by other authors (Caruso *et al.,* 2012). However, a slightly higher nitrate content was detected in the spring season than in the autumn season, and this result was contrary to the findings of Caruso *et al.* (2012).

The treatments L2P2 and L2P3 had higher quality indicators such as reducing sugars, vitamin C, and Brix values than the remaining treatments. All the treatments had nitrate content residue levels below the allowed threshold for safe vegetable production.



Note: Values within a stage for each treatment followed by the same uppercase letter are not significantly different at the 0.05 probability level by Tukey's test.

Figure 6. Effects of furrow height (L) and manure compost level (P) on the average asparagus spear weight



Note: Values within a stage for each treatment followed by the same lowercase letter are not significantly different at the 0.05 probability level by Tukey's test.

Figure 7. Effects of furrow height (L) and manure compost level (P) on the harvested yield of asparagus spears

Conclusions

Asparagus spear diameter increased when the furrow height reached 35cm, but increasing the height to 50cm the did not increase the diameter of the spears, while the highest level of manure compost (50 tons ha^{-1}) gave the highest spear diameters. Increasing the furrow height and the amount of compost resulted in the increased dry matter weight of the spears, of which, the L2P3 and L3P2 treatments had the highest dry matter weights of 8.1g and 8.0g per 100g of fresh weight in the 2019 autumn season, respectively

Table 1. Effects of furrow height (L) and manure compost level (P) on the quality of asparagus spears

Treatments	Reducing sugars (%)		Vitamin C (mg/100g FW)		Brix		Residual NO3- (mg/kg FW)	
	Autumn 2019	Spring 2020	Autumn 2019	Spring 2020	Autumn 2019	Spring 2020	Autumn 2019	Spring 2020
L1P1	2.18±0.10	1.18±0.04	57.4±2.3	51.5±2.7	5.2a	4.7a	221.4±6.7	205.7±5.90
L1P2	2.20±0.07	1.20±0.02	63.8±6.0	54.7±3.6	4.6a	4.7a	215.8±8.7	213.4±6.80
L1P3	2.49±0.03	1.69±0.03	56.1±11.0	50.3±2.5	5.3a	4.7a	252.4±3.1	220.1±7.20
L2P1	2.73±0.35	1.93±0.01	76.8±2.2	73.0±1.3	5.0a	4.5a	171.4±9.1	240.4±8.30
L2P2	3.03±0.12	2.05±0.05	95.6±6.0	83.6±3.8	4.9a	4.8a	220.5±9.6	243.2±11.9
L2P3	2.74±0.13	2.09±0.10	95.5±5.9	85.6±1.3	5.1a	4.7a	221.2±12.3	254.0±17.6
L3P1	2.77±0.09	1.97±0.08	64.5±3.9	56.8±2.4	5.1a	4.7a	203.4 16.6	215.8±12.2
L3P2	2.79±0.07	1.88±0.10	68.3±8.3	58.2±4.1	4.8a	5.2a	203.2±9.4	227.3±13.5
L3P3	2.92±0.80	1.94±0.07	63.7±6.0	59.0±1.5	4.9a	4.5a	239.8±5.4	230.0±10.4

Note: Values within a stage for each treatment followed by the same lowercase letter are not significantly different at the 0.05 probability level by Tukey's test. FW: fresh weight

while L2P2 treatment gave the highest dry matter weight of 5.2g per 100g of fresh matter. The average number of spears per plant increased as the compost level and furrow height increased, with the highest number of spears in the 2019 autumn season being produced at the furrow height of 50cm (L3) and compost amount of 35 tons ha-1 (P3), while in the 2020 spring season, the number of spears per plant was highest at the furrow height of 35cm (L2) and compost level of 35 tons ha^{-1} (P3). The harvested yield of green asparagus was highest at the furrow height of 35cm (L2) and compost level of 35 tons ha^{-1} (P3) in both seasons. The quality of asparagus grown under organic methods at the furrow height of 35cm (L2) and compost level of 35 tons ha^{-1} (P3) gave higher contents of reducing sugars, vitamin C, and Brix values compared to the other treatments, while the residual nitrate content was below the allowed safety threshold in all of the treatments.

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