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Growth and rhizome yield of Ginger *(Zingiber officinale)* using plantlets with various heights as planting materials

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Abstract

In ginger farming, the budget for matured rhizomes as planting material is usually the highest among the cost of production. To reduce the budget cost, the study used plantlets with different initial heights as planting material. The plantlets were propagated through sowing matured rhizomes and were gathered two months after sowing. The treatments of the study are: T_0 - 25g (rhizome sett), T_1 - 20cm (initial height of plantlets), T_2 - 30cm, T_3 - 40cm and T_4 - 50cm. This study evaluated the height and number of tillers of the ginger during their 3rd and 5th months after transplanting (MAT) and the rhizome yield during harvesting period. Result revealed that at three months after transplanting (MAT), the plantlets with initial height of 50cm (T_4) were the tallest and produced the highest number of tillers during the 1st, 2nd and 3rd trials on June 2018 to February 2019, June 2019 to February 2020 and June 2020 to February 2021 respectively. On the other hand, at five MAT, the plants of T_0 were the tallest and have the highest number of tillers per hill during the 1st, 2nd and 3rd trials during the three years of implementation. Further, during harvesting, T_4 has the highest mean of computed rhizome yield per hectare during the three years of implementation. The results could be attributed to the bigger diameter and taller stem of the plantlets which stored more nutrients that sustained the growth and development of the ginger.

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Introduction

Ginger (*Zingiber officinale)* plants are native to South and Southeast Asia (Rafiq *et al*., 2009). The pungent smell of the rhizomes makes it an important in flavoring of foods not only in Asia but also in other parts of the world. Moreover, ginger was used too as treatment of illness that increases its commercial significance (Schwertner and Rio, 2007. Likewise, Mody *et al.* (2012) stressed that the economic importance of ginger did not weakens. Further, ginger is regarded by the marginal or the smallholder farmers as a high-value and profitable crop. The yearly per capita consumption of the Philippines with ginger was more from 0.26kg to 0.36kg on 2012 to 2016. Moreover, during the same period, ginger importation has increased from 1,495 to 8,961 MT (FAO, 2019).

In crop production, ginger is one among the major cash crops cultivated by farmers in the upland areas because of its high price, stable market and high demand. The main constraint in ginger production is the cost of matured rhizomes to be used as planting materials because the price is high most especially during planting period. The farmers usually planted 20 to 30 g seed rhizomes that requires 1,300 to 2,000kg of matured rhizomes to plant one hectare farm. According to Bera and Moktan (2006**),** the cost of planting material is the highest in ginger farming which consist 70% from the total production cost. Hence, an alternative low cost planting material is needed wherein plantlets can be considered which can be propagated through tissue culture and by sowing the matured rhizomes on seedbed.

Plantlets propagated from the matured rhizomes are cheap and the process is simple that can be adopted by any farmers. It is done by sowing the matured rhizomes on a seedbed for two months with several plantlets emerged per sett with a plant height ranging from 25-50cm. Then the plantlets can be directly transferred to the field with assurance of very high survival rate due to bigger size of the stem and has several sturdy roots that will support its initial growth. Additionally, the mother rhizomes sown could still be recovered and use or sold as food ingredient or flavoring.

On the other hand, plantlets propagated through tissue culture method are expensive due to the use of laboratory facility, chemicals, electricity and maintenance cost which are very expensive. Moreover, the laboratory procedure is very complicated and it requires an expert to perform the protocol. Further, according to Gupta and Verma (2011), the major concern and constraints of its worldwide adoption and commercialization is the unsuccessful direct field transfer, It required pre-hardening by transplanting on polyethylene bag and then grown in the nursery for several months. The hardened plantlets will be transplanted to produce microrhizomes. Then the microrhizomes will be planted to produce bigger size rhizomes to be used as the planting materials for commercial rhizome production. Further, Lawal, *et al.* (2016) stated that the growth and yield is usually affected by the size of planting materials wherein the size of the tissue cultured plantlets are too small. Hence, the study was conducted to evaluate the growth and rhizome yield performance of ginger as affected by the initial height of plantlets used as planting materials propagated through sowing of matured rhizome.

Materials and methods

Location of the study

The study was conducted at the Horticulture Farm of the Don Mariano Marcos Memorial State University, Bacnotan, La Union, Philippines. There were three trials conducted covering the period from June 2018 to February 2019 (1st trial), June 2019 to February 2020 (2nd trial) and June 2020 to February 2021 (3rd trial).

Preparation of seedbed used in sowing rhizomes for plantlets propagation

The selected area for sowing the ginger rhizomes was at a partially shaded part of the farm with some trees at the surroundings. The experimental area was cleared from any stones, grasses tree debris and stubbles and plowed twice using hand tractor. Five seedbeds measuring 1.0 m wide and 5.0 m long were prepared.

Preparation of seed rhizomes and sowing

Matured rhizomes of local variety with good quality, without diseases and no damage were procured from the farmer-producer within the community.

The rhizomes were then divided into 50 grams per sett, dipped in Sodium hypochlorite with 0.5% concentration to disinfect then placed on a shaded area for three days to drip and to hasten callousing at the cut portion of the rhizomes and to minimize or eliminate the presence of diseases due to possible contamination.

The rhizomes were then sown on the seedbeds at 10cm apart with a depth of three to five centimeters. Sowing was done ahead for two months prior to planting season or before the onset of rainy season. The seedbeds were then mulched with 3cm thickness of dry grasses and then irrigated immediately. Cultural management was done uniformly during the propagation such as irrigation every three days in the absence of rain, occasional removal of weeds and pest control.

Preparation of the experimental site

The selected experimental area was located on a partially shaded with surrounding trees at the Experimental Farm. Prior to transplanting, the experimental area were cleared from grasses and stubbles of previous plants then plowed twice at an interval of two weeks to pulverize the soil and exposed to sunlight for the elimination of any soil-borne pathogens. The experimental area was laid out and arranged following the Randomized Complete Block Design (RCBD) in three blocks. There were five rows in every plot with 20 hills per row at a distance of 50cm between rows and 30cm between hills. The measurements of the plots are 2.5 m x 6.0 m with an alley of 0.75 m between plots.

Treatments

The treatments of the study are the initial heights of the plantlets used as planting materials and the 25 g seed rhizomes. The treatments are as follows: T_0 (25g seed rhizomes with three to four active buds), T_1 (20cm initial height of plantlets), T_2 (30cm initial height of plantlets), T_3 (40cm initial height of plantlets), T_4 (50cm initial height of plantlets).

Gathering and preparation of planting materials

The mother rhizomes with grown plantlets were dug two months after sowing (MAS). The plantlets were then detached from the mother rhizomes and sorted as to the required height for the respective treatments. Their leaves were partially trimmed to minimize transpiration and dipped in a mixture of fungicide and insecticide following the recommended dilution of the manufacturer to ensure higher survival rate when transplanted in the field. On the other hand, the recovered mother rhizomes sown for the propagation of plantlets were air dried in a shaded area before it was sold and used as ingredient of foods.

Transplanting of plantlets

Prior to transplanting, holes were drilled on the plots at a distance of 30cm between hills and 50cm between rows. The planting of rhizomes (T_0) and transplanting of plantlets (T_1, T_2, T_3, and T_4) were done in the pre–drilled holes. The newly planted rhizomes and transplanted plantlets were irrigated immediately for faster emergence and recovery respectively.

Cultural management

The experimental plots were regularly cleared from emerging and growing weeds. Hilling–up was done on the 4^{th} month to cover the developing rhizomes from direct exposure to sunlight. Occasional spraying with insecticide was also done to eliminate the incidence of insects during their vegetative stage.

Data collection

The height of the ginger at three and five MAT was measured from the ground level to the tip of the tallest leaf. The number of tillers at three and five MAT was counted from the 30 sample plants taken at the three middle rows within the plot. Gathering of rhizomes was done when the leaves and pseudo stem of the ginger has begun to dry on the nine MAT. The rhizome yield was taken from the 30 sample plants at the inner rows and hills of the plot. Rhizome yield per hill and per plot were weighed and recorded. The yield per hectare was computed by converting the actual rhizome yield of the 30 sample plants in a plot into a per hectare basis.

Statistical analysis

Analysis of variance among the treatments was done using the Statistical Tool for Agricultural Research (STAR) Version: 2.0.1. (International Rice Research Institute).

The Tukey's Honest Significant Difference (HSD) Test was also used to determine the significant differences between the treatment means at 5% level of significance.

Results and discussions

Plant height

The height of ginger at MAT has significant differences among the treatments. The tallest plant was observed in T_4 during the 1st trial (June 2018 – February 2019), 2nd trial (June 2019 – February 2020 and 3rd trial (June 2020 – February 2021 with 56.80, 77.35 and 74.20cm respectively, which is significantly differed to the other treatments (T_0-T_3) with shorter planting materials with height ranging from 39.49 - 60.77cm after three MAT (Table 1). Likewise, at five MAT, a significant differences was observed on the height among the treatments in all the three trials conducted wherein the plants of T_0 were the tallest with 87.23cm, 88.53cm and 89.78cm during the 1st, 2nd and 3rd trials respectively but comparable to the height of the plants in T_4 with 86.33cm, 86.51cm and 88.13cm during the 1st, 2nd and 3rd trials respectively. However, the plants of T_0 and T_4 are significantly taller ranging from 42.07- 69.80cm during the three trials than the other treatments with shorter initial height (Table 2).

Table 1. The height of gingers at 3 months after transplanting (MAT) as affected by the initial height of plantlets as planting materials.

Treatment	Plant height, cm		
	1st Trial June 2018-February 2019	2nd Trial June 2019-February 2020	3rd Trial June 2020-February 2021
T_0 – 25g rhizomes	32.40^{c}	51.42^{bc}	42.70^{cd}
T_1 – 20cm plantlets	32.27^{c}	39.53^{d}	39.49^{d}
T_2 – 30cm plantlets	38.33^{bc}	48.30^{c}	48.00^{c}
T_3 – 40cm plantlets	47.40^{ab}	58.83^{b}	60.77^{b}
T_4 – 50cm plantlets	56.80^{a}	77.35^{a}	74.20^{a}

*All means in a column followed by the same letter are not significantly different at 0.05 level Tukey's Honest Significant Difference (HSD) Test.

Table 2. The height of gingers at 5 MAT as affected by the initial height of plantlets as planting materials.

Treatment	Plant height, cm		
	1st Trial June 2018-February 2019	2nd Trial June 2019-February 2020	3rd Trial June 2020-February 2021
T_0 – 25g rhizomes	87.23^{a}	88.53^{a}	89.78^{a}
T_1 – 20cm plantlets	43.70^{d}	42.07^{d}	45.11^{d}
T_2 – 30cm plantlets	53.37^{c}	51.30^{c}	56.23^{c}
T_3 – 40cm plantlets	64.60^{b}	60.85^{b}	69.80^{b}
T_4 – 50cm plantlets	86.33^{a}	86.51^{a}	88.13^{a}

*All means in a column followed by the same letter are not significantly different at 0.05 level Tukey's Honest Significant Difference (HSD) Test.

The result conformed to the previous studies that the growth of the plantlets or seed rhizomes with bigger size are faster to grow or taller in height because there are more nutrients being stored in a bigger rhizome seeds that supported the growth of the ginger (Blay *et al.,* 1998; Hailemichael and Tesfaye, 2008), and in turmeric (Hossain *et al.,* 2005). The highest plant height was recorded from very large seed rhizome while the shortest was recorded from small seed rhizome at 125 DAP.

Fig. 1. The ginger plantlets with various heights.

Likewise, Smith (2000) reported a similar result on his study as cited by Sathyagowri and Seran (2011) that the production of shoots through tissue culture has longer number of days to sprouting than the explant with bigger size because of the availability of more nutrients in the explant. Bigger size of explant has more nutrients reserve and endogenous

phytohormones to support the initial growth of tissue culture. On the other hand, the result of the study of Razdan (2003) as cited by Sathyagowri and Seran (2011) revealed that micro-propagation from smaller explant tips has slow initial growth.

Number of tillers

The plants of T_4 was significantly had the most number of tillers at three MAT with 7.77, 7.70 and 8.22 tillers per hill during the 1st, 2nd and 3rd trials respectively than the other treatments with shorter initial height as planting materials ranging from 3.67-5.90 tillers per hill (Table 3). However, at 5 MAT, the plants of T_0 produced the most number of tillers throughout the three years trial conducted with 13.30 (1st trial), 14.33 (2nd trial) and 13.83 (3rd trial) but comparable to T_4 with 12.70, 13.10 and 13.53 tillers during the same period, but are significantly differed to the other treatments with shorter initial height ranging from 6.83 - 10.16 tillers per hill (Table 4).

Table 3. Number of tillers of gingers at 3 MAT as affected by the initial height of plantlets as planting materials.

Treatment	Number of tillers		
	1st Trial June 2018-February 2019	2nd Trial June 2019-February 2020	3rd Trial June 2020-February 2021
T_0 – 25g rhizomes	4.33^{bc}	4.03^{bc}	4.73^{b}
T_1 – 20cm plantlets	3.86^{c}	3.67^{c}	4.01^{b}
T_2 – 30cm plantlets	4.63^{bc}	4.33^{bc}	4.77^{b}
T_3 – 40cm plantlets	5.69^{ab}	5.90^{ab}	5.80^{b}
T_4 – 50cm plantlets	7.77^{a}	7.70^{a}	8.22^{a}

*All means in a column followed by the same letter are not significantly different at 0.05 level Tukey's Honest Significant Difference (HSD) Test.

The result could be attributed to the size of planting material because the largest rhizome size emerged earlier and showed vigorous and rapid growth using the initial reserve food materials in it. Monnaf *et al.* (2010) reported similar result of their study that the rhizome size had significant influence on the various growth parameters of ginger wherein the 30 - 35g rhizome used as planting material have the tallest plant height, highest number of leaves per plant, number of tillers per clump, highest yield per plant and per plot, while the lowest were found in 10 - 15g seed rhizome.

Table 4. Number of tillers of gingers at 5 MAT as affected by the initial height of plantlets as planting materials.

Treatment	Number of tillers		
	1st Trial June 2018-February 2019	2nd Trial June 2019-February 2020	3rd Trial June 2020-February 2021
T_0 – 25g rhizomes	13.30^{a}	14.33^{a}	13.83^{a}
T_1 – 20cm plantlets	6.89^{c}	6.83^{c}	7.63^{c}
T_2 – 30cm plantlets	8.97^{b}	9.57^{b}	9.88^{b}
T_3 – 40cm plantlets	9.30^{b}	9.93^{b}	10.16^{b}
T_4 – 50cm plantlets	12.70^{a}	13.10^{a}	13.53^{a}

*All means in a column followed by the same letter are not significantly different at 0.05 level Tukey's Honest Significant Difference (HSD) Test.

Rhizome yield

The plants of T_4 (50cm initial height during planting) produced the highest rhizome yield per hill with 165.00 g, 222.90 g and 183.30 g per hill during the 1st, 2nd and 3rd trials respectively. Moreover, it also produced the highest computed yield per hectare during the same period with 11.00, 14.86 and 12.22 tha^{-1}, followed by T_0 (25 g rhizome as planting material) with 7.10, 12.08 and 10.06 tha^{-1}. The lowest yield was attained by the treatments with the shortest initial height at transplanting (T_1 - 20cm) with 4.57, 7.75 and 4.61 tha^{-1} during the same period too (Table 5).

The treatment with the tallest initial height at planting time attained the highest yield, while the plantlets with shortest initial height exhibited the lowest yield. The yield was greatly affected by the initial height of the planting materials during planting period. The optimum yield per plant, per plot and per hectare was obtained from the very large seed rhizome and the lowest per plant, per plot and per hectare was recorded from the small seed rhizome.

It might be due to bigger size of the seed rhizome that sustained vigorous growth than those of the smaller ones, which in the deposition of greater amount of photosynthates in the rhizome. The size of rhizome or plantlets used as planting materials have significant influence on the growth (Mahender *et al.*, 2015) and rhizome yield of the ginger (Asafa and Akanbi, 2018; Zaman *et al.*, 2002; Enyi, 1972). Similarly, Whiley (1990) and Borget (1993) also stated that using bigger seed rhizomes as planting materials have great effect in improving the ginger rhizome yield. Likewise, Angami *et al.* (2017) and Islam *et al.* (2017) reported too that the growth and yield of ginger is higher by the use of bigger seed rhizome.

Table 5. Rhizome yield per hectare of ginger as affected by the initial height of plantlets during planting.

Treatment	Rhizome yield					
	1st Trial June 2018-February 2019		2nd Trial June 2019-February 2020		3rd Trial June 2020-February 2021	
	per hill (g)	per hectare (ton)	per hill (g)	per hectare (ton)	per hill (g)	per hectare (ton)
T_0 – 25g rhizomes	107.55	7.17^{b}	181.20	12.08^{ab}	150.90	10.06^{ab}
T_1 – 20cm plantlets	68.55	4.57^{c}	116.25	7.75^{bc}	69.15	4.61^{c}
T_2 – 30cm plantlets	94.05	6.27^{b}	138.00	9.20^{b}	115.05	7.67^{b}
T_3 – 40cm plantlets	114.00	7.60^{b}	163.20	10.88^{b}	144.15	9.61^{ab}
T_4 – 50cm plantlets	165.00	11.00^{a}	222.90	14.86^{a}	183.30	12.22^{a}

*All means in a column followed by the same letter are not significantly different at 0.05 level Tukey's Honest Significant Difference (HSD) Test.

Conclusions

The height, number of tillers and yield of the ginger plants greatly depends on the size of the planting materials due to the presence of readily available nutrients stored in the plantlet itself to support the growth and rhizome development. Therefore, bigger plantlets were faster in their initial growth due to more nutrients stored within the plant system. Results revealed that planting materials with an initial height of 50cm (T_4) were the tallest and had the highest number of tillers at three MAT, while the control treatment (T_0) has the highest growth increment due to the availability of sufficient nutrients stored in the rhizomes that boost its growth. During the 5th MAT, the treatment T_0 have the tallest height and more number of tillers due to longer availability of nutrients stored in the rhizomes that sustained the growth at later growth stage but comparable to T_4. The highest rhizome yield was attained by T_4.

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Declaration of interest

The authors declare that there is no conflict of interest.

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