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Determination of seed rate and row spacing planting density on corm size yield and quality components of taro (*Colocasia esculenta* L.)

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Abstract
Field experiment was conducted to examine the effect of type of planting material and plant population density on the yield and its components during the main rainy season at from East Gojjam from lowlands for Abay river basin with the experiment conducted Mertulemariam Agricultural TVTE April 2017 to January 2018 in a split- plot design with three replications. The treatments included a factorial combination of two type of planting material of variety Boloso -1 and 12 densities through different arrangements (35, 50, 65, and 80cm) inter and (50, 70, 90 and 110cm) intra row spacing. The result showed that type of planting material had a significant ($p<0.05$) effect on 50% emergence, number of leaves, leaf area, weight of corm and dry matter percentage per plant and total, marketable and unmarketable yield (tha^{-1}). Corms achieved 50% emergence earlier than cormels, they also recorded higher mean height, leaf number, shoot number, leaf area, corm weight and corm diameter per plant as well as higher total and marketable yield (tha^{-1}). Plant population density had a highly significant ($p<0.001$) effects on number of suckers, corm diameter, number of corm, weigh of corm, leaf area index per plant and total, marketable and unmarketable corm yield (tha^{-1}). Total yield, marketable and unmarketable yield of corm yield increased with increasing planting density while the mean corm weight per plant decreased at higher densities. The highest average total yield (49.85tha^{-1}) were obtained at 25,973 plants ha^{-1} with marketable yield of 37tha^{-1} that is followed by 40.5tha^{-1} were obtained at 31,745 plants ha^{-1} with marketable yield of 27 tha^{-1}. Type of planting material and population density interaction had a significant ($P<0.001$) effect on total and marketable corm yield (tha^{-1}) with their maximum density at 25,973 plants ha^{-1}. Therefore, to maximize yield and still to properly earth up, population density of 25,973 plants ha^{-1} (35cm x 110cm) could be recommended. In conclusion, total and marketable yields were maximized at 25,973 plants ha^{-1} for both corm and cormel type of planting material for marketable and unmarketable (for planting) taro production.

Keywords: taro, spacing, lai, yield, yield component, planting material, density

Introduction

Taro (*Colocasia esculenta*) is grown in nearly all parts of the humid tropics in more than 65 countries worldwide and serves as an important staple food and as a source of carbohydrate for inhabitants in some subtropical and virtually all tropical regions (LEISA, 2004). It is cultivated mainly in developing countries, rarely on large plantations but on small farms with little technology

Crop research in Ethiopia has largely concentrated on the more important cereal, oil and industrial crops. The rather localized importance of indigenous vegetables seems to be part of the reason for the lack of national research focus. Most of the traditional vegetable and root crops of Ethiopia are produced by small farmers following traditional practices. There is no direct attention paid to package production and non-cultivated species. They are not fully documented and no programmes are currently aimed at their development and production.

Taro is native to South India and Southeast Asia. It is a perennial, tropical plant primarily grown as a root vegetable for its edible starchy corm, and as a leaf vegetable. It is a food staple in African, Oceanic and South Indian cultures and is believed to have been one of the earliest cultivated plants. *Colocasia* is thought to have originated in the Indo-Malayan region, perhaps in eastern India and Bangladesh, and spread eastward into Southeast Asia, eastern Asia, and the Pacific islands; westward to Egypt and the eastern Mediterranean; and then southward and westward from there into East Africa and West Africa, whence it spread to the Caribbean and Americas. It is known by many local names and often referred to as "elephant ears" when grown as an ornamental plant.

Soil preparation for upland taro is similar to that for most upland crops, such as corn. Existing vegetation is turned under with a moldboard or disc plow, or by spading. Incorporate phosphate fertilizer, if required, during cultivation; also, most soils benefit from adding compost. After a few days to allow for decomposition, break soil clods by harrowing or motivating or, in small gardens, with a hoe or rake. After the soil has been pulverized, the surface may be smoothed in preparation for planting. Upland taro can be planted on ridges, in furrows, or on flat ground. Prepare rows, and use a guide string to plant 18-24 inches apart within rows 18-24 inches apart.

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(Chien-Chun *et al.*, 2006). Taro ranked 14th among staple crops in 1987 in terms of volume of production (Hollyer, 1997) [17]. According to the FAO (2007) [13] statistical report, world taro production in 2005 was over 11.7 million metric tons from an area of 1,781,270 hectare of land with global average yield of 6.5 ton/ha. The top 6 producing nations are Nigeria, Ghana, China, Cambodia, Côte d'Ivoire and Papa New Guinea, respectively (FAO, 2007) [13]. The bulk of production is in Africa, Nigeria and Ghana producing 5.1 and 1.8 million metric tons from an area of 667,000 and 270,000 hectare, respectively; however, its intensity of cultivation and highest percentage contribution to the diet occurs in the Pacific Islands (Onwueme, 1999) [29].

In Ethiopia, a total of 26,506.36 hectares of land in 2001/02 cropping season was covered by taro (CACC, 2003) [5] and the production is estimated to be over 190,000 tons (MARD, 2005). Out of the total taro area cultivated in 2001/02 cropping season, the bulk of production of taro (20,100.48 ha) was in Southern Nations Nationalities and Peoples' Regional State (SNNPRS), followed by Oromia (6,147.87 ha), Gambella (231.84 ha) and Benishangule Gumuz (9.36 ha) regions (CACC, 2003) [5]. In Wolaita zone of the SNNPRS, 29.59% of the crop area was under sweet potatoes, potatoes and taro each covering 66.5%, 18.5% and 14.2% of the production area, respectively. The total area under taro cultivation in the zone was 4,202.46 ha, accounting for 16% of the country and 30% of the regional share (CACC, 2003) [5]. Farmers in Wolaita have identified about seven different clones of taro locally known as *Gerezua*, *Shishia*, *Yittria*, *Moliya*, *Tawayia*, *Gesa*, *Woldua* and *Kawo Boina* (cultivar *Kawo Boina* belonging to the genus *Xanthosoma)*, on the basis of morphological, phenological, agronomic and quality traits, and fitness into cropping systems and medicinal values (Asfaw, 2006; Simon, 1992) [3, 36].

At present, there has been an increase in the area of production of taro in SNNPR, BGR and Amhara region food security low land area the level of dependence on sweet potato and enset crop is shifting to maize and taro in Wolaita (Asfaw and Waga, unpublished) due to enset bacterial wilt, sweet potato butterfly and the introduction of high yielding taro variety, Boloso-1. In Ethiopia, taro is highly prized and is a dominant staple food crop in subsistent sector and an important source of cash income (Simon, 1992) [36]. The corms and cormels (in Ethiopia) as well as the leaves are the main economic part of taro plant are rich in starch and eaten in a manner similar to potatoes; boiled, baked, roasted, fried or as a basis for soups (Kay, 1987) [22]. In Ethiopia, corm/cormels boiled and eaten similar to potato, mixed with other vegetables, butter and garlic (Asfaw, 2006) [3]. Corm/cormels are considered as a good source of carbohydrates which considered as excellent for people with digestive problems, for people with allergies, such as lactose intolerance, and as canned baby foods (Matthews, 2004) [24]. In comparison with potato, taro corm has a higher proportion of protein (1.5-3.0%), calcium, and phosphorus; it has a trace of fat, and is rich in vitamins A and C (Hsiu-Ying Lu *et al.*, 2005) [18]. Oxalic acid may be present in the corm and especially in the young leaf (Matthews, 2004) [24]. Traditionally taro is vegetatively propagated plant species but some species flower and produce seeds naturally while others can be induced to produce seeds by spraying gibberelic acid (Tyagi and Deo, 2005) [39], in some clones flowering is sporadic and the seed are tiny (Jill, 1990) [20]. Types of planting materials that are used for propagation of taro production are: side suckers, small corms (unmarketable), huli i.e. the apical 1-2cm of the corm with the basal 15-20cm of the petioles attached; corm pieces (resulting when large corms are cut into smaller pieces) and whole corms (Onwueme, 1999) [29]. Because of the profusion of buds on the corm and cormel, taro conventionally established from intact corms, intact cormels, or piece of corm and cormels (Onwueme and Sinha, 1991). In Wolaita and other taro growing areas in the country, there is inadequate supply of planting material as the corm and cormels are often fully consumed by the family, leaving too little for planting material (Simon, 1992) [36].

The taro leaf, like other higher plant leaves, is rich in protein. It contains about 23% protein on a dry weight basis. It is also a rich source of calcium, phosphorus, iron, Vitamin C, thiamine, riboflavin and niacin, which are important constituents of human diet (FAO, 1999) [29]. Taro is rich in energy or carbohydrate, low in fiber and a faire source of fat and oils. When it is compared to Tannia and other root crops it has highest content of Phosphorus, Magnesium, and Zinc. Like most plant origin foods taro also contains a variety of anti-nutritional and toxic components. Taro contains oxalates, phytates trypsin and amylase inhibitors, phytates, tannins and cyanide in some cultivars. Therefore is very important to processes taro before consumption. Taro is an important food crop in world, taro leaves are used as a vegetable in laulau, and taro corms are made into poi. Corms are also boiled, steamed, and baked, and may be fried to make chips

(http://www.ctahr.hawaii.edu/fb/taro/taro.htm#top).

In Ethiopia, some studies have been conducted on the effect of plant population density and type of planting material of taro on yield in few locations (Jimma and Areka) but there is no sufficient information on the yield response of taro to population density and type of planting material for different agro ecological zones of the country (Edossa *et al*., 1995; Simon, 1992) [7, 36]. The recommendation of 40,000 plant ha^{-1}, (50cm x 50cm) spacing has been used for the variety Boloso–1 and local varity in the study in area. However, this density was recommended without considering type of planting material and was also not acceptable by farmers as farmers said it is narrow (Personal communication). Elsewhere in the Asian Pacific Onwueme and Sinha (1991) recommended spacing results of 60 cm between plants and between rows (27,660 plants per ha) for optimum production of taro. Such differences show the need for determining plant population density for optimum yield of taro. The main objective of this study was therefore, to determine the effect of type of planting material and plant population density that maximize taro corm yield of improved to the area.

Materials and Methods

Description of the Study Area

A field experiment was conducted during the 2017 summer season -cropping season at the field experiment in MATVTE. It is located at 365 km North of Addis Ababa and 13 km from Mertulmariam Town, east direction to to south wello found at 7□05" 95'N latitude and 37□40".330'E longitude and altitude of 1965 meters above sea level (m.a.s.l). The soil at the center is formed from pyroclastic rocks and clayey in texture. The mean annual rainfall is 1750 mm and has a bimodal pattern that extends from May to last September. The mean peak rainy months are April, August and September (281.4 mm, 275.7mm and 271.5mm, respectively). The mean annual minimum and maximum temperatures are 15ºC and 26□C. November is the coldest month whereas March is the hottest.

Experimental Detail

Experimental material and design

The treatments consists of (i) four inter (50, 70, 90 110cm) and intra (35, 50, 65,80cm) -row spacings (ii) two types of planting material (corm and cormels). The experiment was laid out as a split–plot design with factorial experimentation with three replications. Two type of planting materials and sixteen possible spacing combinations were randomly arranged in the main plot and sub-plot, respectively. The sixteen spacing arrangements (treatments) used were presented in table 1.

The variety used was Boloso-1, which is a recently released variety. The variety is dasheen type. It was planted on 25 August 2017 Each replication contained two main plots (planting materials) and sixteen sub plots (spacing combinations) from which the inner four rows were sampled. The experiment was surrounded by two rows of guard plants. Each plot differed in total area depending on the intra and inter- row spacing. The gross plot size also varied, each consisting of six rows and contained different number of plants, the smallest and the highest number of plants per hectare was 13,363 and 57,143, respectively.

Cultural practices

Taro is a staple food throughout the subtropical and tropical regions of the world. And can be consumed as both a staple food and vegetable, and processed as a food ingredient, animal feed, etc (FAO, 1999) [29]. Taro has much importance in ensuring food security, in earning foreign currency as being a cash crop and also as a means for rural development. Moreover, it has been reported to have a wide range of uses in religious festivals, as mild laxative, in treatment of wounds and snake bites, reducing body temperature in a feverish patient and others (FAO, 1999) [29]. Nutritionally, Taro contains more than twice the carbohydrate content of potatoes and yield 135 kcals per 100 g. Taro contains about 7% protein on a dry weight basis.

Cormels with the same weights of Bout 100 g were used as planting materials. Cultivation and all cultural practices (irrigation, fertilization, weeding, and pest control), according to the recommendations of the Ministry of Agriculture, were kept normal and uniform for all the treatments.

Planting materials used were fresh mother corm and cormels of variety Boloso-1 obtained from welayita They were harvested from plants of the 2017 cropping season. In order to facilitate sprouting, corm and cormels were dug out and left under shade (open air) and planted 10 days later. Uniform corm and cormels sizes were selected visually excluding over and under sized corm and cormels. No fertilizer was applied throughout the growing season. The experimental area was hand weeded as necessary. The land was deep plowed and disked with tractor and then oxen plowed and finally leveled with manual labor. Incidence of disease, insect damage, frost, and storm did not occur except unusual extended rainfall and few occurrence of mole rat (*Heterocephalus glaber*). A onetime harvest was made on 2 January, 2007. Both pre-harvest and post-harvest on Plant height (cm), Number of green (functional) leaves per plant, Leaf area per plant (cm^2),Maximum leaf length (Lx),Maximum leaf width (Wx),Leaf area index (LAI),Corm length (cm),Corm diameter (cm), Number of corm, Corm fresh weight per plant (g plant^{-1}),Marketable yield (tha^{-1}),Unmarketable yield (tha^{-1}), Corm dry matter percentage and Yield per hectare (tha^{-1}) were recorded.

Statistical analysis

Analysis of variance was conducted using SAS programs (SAS 9.1). The experiment was analyzed as a split- plot design with main plot planting materials (Pm) and sub plot of spacings (Sp). A probability level of $p \leq 0.05$ was considered to be statistically significant and significant means were separated using Tukey's - test.

Results

Date of 50% Emergence

Type of planting material significantly ($p \leq 0.05$) affected date of emergence. Corms achieved 50% emergence 32.9 days after planting (DAP) whereas cormels at 35.6 DAP (Table 4). Neither population density nor their interactions had significant effect ($p \leq 0.05$) on date of 50% emergence.

Plant Height

Plant height increased from a minimum of 39.18cm at two months after planting (MAP) to a maximum of 80.79cm at 7MAP; thereafter, it declined (figure 1). Analysis of variance revealed that plant height was affected significantly ($p \leq 0.05$) by source of planting material at 2, 4, 5, 6, 7, 8 and 9 MAP. Corm recorded a significantly high mean height per plant at all moths after planting (MAP).

Plant population density had no significant ($p \leq 0.05$) effect on plant height at all MAP. The height of plants differed very little in relation to density (figure 1). There was no interaction effect of plant population density and type of planting material on plant height.

Number of Leaves

Type of planting material had significant ($p \leq 0.05$) effect on leaf number per plant. Plants grown from corms recorded significantly higher number of leaves throughout the growing period except at 9 MAP (Table 2). The magnitude of the difference in mean number of leaves per plant from the two sources of planting materials was highest at 3 (4.03 leaves), 4 (4.46), 6 (4.63) and 8 (3.65) MAP. It was also observed that corms begin to develop leaves and suckers earlier than cormels due to difference in date of 50% emergence. Similarly, the experimental plots planted with corm had greater number of active (living) leaves than cormel plots. The number of leaves increased and reached maximum 5MAP and declined thereafter (Figure 2).

Number of Shoots

Number of shoots per plant responded significantly ($p \leq 0.05$) to the type of planting materials at 2, 3 and 4 MAP. Corms recorded higher mean value at 2, 3 and 4 MAP (Table 3). There was little shoot development during the first two month after planting (Figure 3). Thereafter, there was an increase in number of shoots, attaining a peak at about 7MAP for both type of planting materials. After the 7th months, there was no further increase in number of shoots. Shoot number per plant was significantly ($p \leq 0.05$) affected by population density at 2, 5, 6, 7 and 9 MAP. At 3 MAP, the highest mean shoot number per plant was recorded at 28,570 plants ha^{-1}. At 5, 6, 7, and 9 MAP, the highest mean values were recorded at 13,363 plants/ha (Table 3). Shoot number per plant was not affected by density at 2, 4 and 8 MAP. Overall, the highest mean shoot number per plant (6.17) was recorded at 13,363 plants ha^{-1} at 7 MAP. There was no interaction effect between plant population density and type of planting material on number of shoots.

Leaf Area and Leaf Area Index

Type of planting material had a significant effect ($p \leq 0.05$) on leaf area per plant. Corm had scored a significantly higher mean leaf area per plant (4954.2cm^2) than cormels (3, 995.7 cm^2) (Table 4). Type of planting material had no significant ($p \leq 0.05$) effect on LAI.

Population density had no significant ($p \leq 0.05$) effect on leaf area per plant. However, leaf area per plant has shown an increasing trend with the decrease in plant density (Figure 4). Plant density had a highly significant effect ($p \leq 0.001$) on LAI per plant. The highest LAI per plant was recorded at the maximum density (57,143 plants ha^{-1}); the value decreased with decreasing density (Figure 4).

Corm Number per Plant

Type of planting material had no significant ($p \leq 0.05$) effect on mean corm number per plant. However, mean corm number per plant was slightly higher for corm than cormel (Table 5). Plant density had a highly significant ($p \leq 0.001$) effect on corm number per plant. The highest (13.03) and lowest (8.6) mean corm number plant were attained at 13,985 and 57,143 plants ha^{-1}, respectively (Table 5).

Corm Length and Diameter

Planting material had no significant ($p \leq 0.05$) effect on corm length. Nevertheless, plants grown from corm produced slightly longer (mean =11.15cm) corms than from cormels (Table 5). Similarly, density had no significant ($p \leq 0.05$) effect on corm length. However, there were differences in mean corm length per plant among different density level. The highest mean corm length was recorded at 13,888 plants ha^{-1}. This was 4 % higher than the lowest value (9.37cm) scored at 40,000 plants ha^{-1}. Mean corm diameter per plant was not affected significantly ($p \leq 0.05$) by planting material; however, it was highly and significantly ($p \leq 0.001$) affected by density. Corm diameter was highest (7.34) unit at 18,181 plants ha^{-1} (Table 5). It started to decline both at higher and lower density. Mean of the diameter/length ratio (DLR) was not affected significantly ($p \leq 0.05$) due to type of planting material. However, there are variations in the mean corm length/diameter ratio in relation to density. The lowest (0.57) DLR value was recorded at 40,816 plants ha^{-1}; this value was 4% lower than the highest DLR (0.67) recorded at 40,000 plants ha^{-1}

The interaction effects of planting material and density on corm length, diameter and DLR were non-significant ($p \leq 0.05$).

The interaction effects of planting material and density on corm weight and dry matter percent were not significant ($p \leq 0.05$).

Ha^{-1}. Density had a highly significant ($p \leq 0.001$) effect on unmarketable (< 250g) yield per hectare. The highest unmarketable yield (13.68tha^{-1}) was recorded at 31,745 plants ha^{-1}.

Yields of the two categories (total and marketable yield) were very high at higher densities, reached a maximum at 25,973 plants ha^{-1} and start to decline. Whereas the unmarketable yield were maximum at 31,745 plants per hectare (Table 6).

Association among Yield and Yield Components

Correlation of yield and yield components among themselves is presented in Table.7.

Leaf area was significantly ($p \leq 0.001$) and positively correlated with number of leaves (r = 0.42), plant height (r = 0.39), number of shoots (r = 0.35) number of corm (r =0.33) and weight of corm (r = 0.26). Weight of corm per plant was significantly ($p \leq 0.001$) and positively correlated with number of leaves (r = 0.28), plant height (r = 0.30) number of corm (r = 0.54), corm diameter (r =0.47) and leaf area (r = 0.36), per plant. Whereas, corm number per plant was significantly ($p < 0.01$) and positively correlated with number of shoot (r = 0.20), corm diameter (r = 0.36) and LA (r = 0.33). Total corm yield (t/ha) was significantly ($p \leq 0.001$) and positively correlated with leaf area index (r = 0.51) and plant height (r = 0.47).

Discussion

Size and vigor of Shoots

The type of planting material significantly ($p \leq 0.05$) affected plant height, number of leaves of taro and leaf area. Plants grown from corm gave taller shoots, higher leaf number and leaf area than plants grown from cormels. The finding of the present study agree with those reported by Johnston *et al.* (1997) [21] who found significant difference between huli and tissue cultured plants; maximum 14 leaves 15 weeks after planting and 20 leaves 31WAP for huli and tissue culture plants, respectively.

The possible reason for this may be early emerging plants are likely to be more competitive than later emerging plants due to the development of size bias and resulting asymmetric competition. The greater size and vigor of plants from corm can be associated with the fact that corms establish faster than cormels (Table 4). Early canopy development (radiation capture) higher LA and plant height values at 2 MAP (Table 4 and figure 1). More assimilates from corm accounted for the increased size and vigor of plants than cormels.

Density had no effect on shoot length (plant height) and leaf number per plant. The non-significant effect of population density on number of leaves per plant in this experiment agreed with the report of Shih and Snyder (1984) where an increase in trend on leaf number during the early growth (2 MAP) was obtained maximum at 4 MAP with 0.2m plant spacing whereas leaf number at 0.4m and 0.6m plant spacing reached maximum 6 MAP; the number of leaves near the end of growth season reached a similar number in all plant densities. On the contrary, Gill *et al.* (2005) [14] obtained higher number of leaves per plant (8.1) at a density of 74,000 plant ha^{-1} compared to the lowest densities. The finding differs from the report of Gendua *et al.* (2000) [13] who found that plant density significantly affected plant height of taro. They found 10,000 plant ha^{-1} gave taller plant than the 40,000 plant ha^{-1}. Moreover, Igbokwe and Ogbonnaya (1981) [19] obtained that plant height increased with increasing intra row spacing i.e. decreased densities with the application of 40 kg N ha^{-1}.

In most plants (e.g. maize), shoot growth (height, leaf number) reach at an optimum density; further increase in density is associated with decrease in individual plant or stem size. Higher plant densities also had a greater number of vegetative shoots; however, plots with higher initial stand densities reached equilibrium much faster than plots with lower stand densities (Springer *et al*., 2003) [38]. In this study, plant height and number of leaves were the same at all plant densities. The deviation in the pattern of shoot growth observed in taro can be explained by the fact that vertical growth of shoots length of the petioles, sucker production (branching nature of taro) at lower densities, plants formed more shoots than those at higher densities.

Number of Shoots per Plant

Plants raised from corm produced more shoot number per plant than cormel (Table 3). Higher shoots number was produced at 3, 5, 6 and 7 MAP. According to Miyasaka *et al.* **(2003),** root and shoot development with initiation of corm development were observed during one to four months. In this study, corm produced significant higher number of shoots at 2, 3 and 4 months

Gendua *et al.* (2000) [13] also corroborate the result of this study as they found a significant higher average of three basal suckers (shoot) per plant at the higher (40,000 plants ha^{-1}) who concluded that number of shoot per plant decreased significantly with increased plant densities. Similarly, Ezumah (1973) [12] also reported that the contribution of sucker corms to yield increased as plant population decreased. The increased in shoot (sucker) number with decreased in density may be due to greater amount of available assimilates for below ground and the availability of more nutrient, moisture and low competition for light at low densities.

Shih and Snyder (1984) suggest that when suckers (shoots) form leaves with complete photosynthetic ability, they synthesize their own nutrients. The contribution of corm to more number of shoot per plant and the significant correlation between leaf number and shoot number (r = 0.71), shoot number and number of corm (r= 0.21) and shoot number and weight of corm (r = 0.26) obtained in this study can be explained by the relative earlier shoot emergence rate, number of daughter corm and cormel formation less than three months and also the inherent characteristics of corm and cormels in relation to shoot formation and sprouting.

Number of Corm per Plant

Planting materials (corm and cormel) had no significant effect on number of corm per plant. This finding is in agreement with those reported by Edossa *et al.* (1994) [7] who found that using different taro propagules (corm, cut corm and cormel) has no effect on number of corm. On the contrary, Khalafalla (2001) [23] obtained seed size of potato tuber significantly affected number of tuber per plant and number of stems per plant. The smaller variation in number of corm per plant may be due to uniformity of planting material used in this study. Plant population density had significantly affected number of corm. At higher plant density, number of corm decreased and at low densities corm number per plant increases. The result agree with those reported by Ellison *et al.* (1989) [9] in Brazil, who found that maximum production of corm/plant was obtained at lower density of 6,700 plant ha^{-1}. Also, Edossa *et al.* (1994) [7] obtained significant increase in number of corm per plant at lower densities. On the contrary, Safo *et al.* (1991) [31] obtained that density had no significant effect on number of corm per plant. In this study density had significant effect on corm diameter. Higher diameter of corm was obtained at density of 18,181 plants ha^{-1}. On contrary, to this study Safo *et al*. (1991) [31] and Edossa *et al.* (1994) [7] found that spacing had no significant effect on diameter of the corm. The inverse relationship of number of corm per plant and density in this study may be associated with the number of shoots per plant supported by the significant correlation between number of corm and shoot number (r=0.36). Number of corms is an important determinant of the multiplication ratio. Per plant basis, maximum corm number (13) was attained at 13,985 plants per hectare.

Corm Size

Weight of corm and dry matter content of corm were affected significantly ($p<0.05$) by type of planting material. Plants grown from corm gave the highest average corm weight (1283g) than cormels (1028.73g). The result agreed with that of Khalafalla (2001) [23] who reported that seed tuber size of potato (whole, half and farmer's seed piece) affects the marketable tuber weight. The highest corm weight obtained from corm can be explained by the fact that plants grown from corm attain greater number of leaves at relatively early stage of growth and may also be related with size advantage i.e. source/ sink relationship. This is also be reflected in the higher significant correlation observed between number of leaves and number of corm (r = 0.46), number of corm and weight of corm (r = 0.54) leaf area and number of suckers (r = 0.66).

Plant density had significant effect on corm weight per plant. At higher plant density, corm weight per plant decrease and total yield ha^{-1} increased, while the reverse is true at low densities. The highest weight of corm per plant (1.58kg) was obtained at the lowest densities (13,888 and 13,363 plants ha^{-1}). The result of this study agree with that of Gendua *et al*. (2000) [13] who reported that the higher mean corm weight per plant (839g) was obtained from 10,000 plant ha^{-1} and reduced significantly at all plant densities above 10,000 plant ha^{-1}. In addition, Edossa *et al.* (1994) [7] also found a significantly increased corm weight with decreased densities. De La Pena (1978) also reported that corm and cormel weight was inversely related to the number of plants per hectare in both upland and lowland taro. On contrary, Schaffer *et al.* (2005) [33] and Adriano *et al.* (1986) [2] reported that plant density had no significant effect on average corm and cormel weight per plant, respectively. The decreased in corm weight with increasing densities observed in this experiment may be due to lesser plant competition for growth resources per plant. The average dry matter percentage and diameter length ratio of Boloso-1 in this experiment was 36.7% and 0.63, respectively. Diameter/length ratio of 0.6 to 0.85 (oval) and 0.85 to 1.0 (round) shapes are the most acceptable than “dump ball” shape (0.35 – 0.5) (Gregory, 2004). Percent dry matter of corms of 20% is considered to be the minimum acceptable to consumers and dry weight of higher than 40% is considered as poor eating quality (Miyaska *et al*., 2001). The results showed that, variety Boloso-1 fulfill some quality parameters, which indicate the potential of this variety for food security, income generation and commercialization.

Optimum Density

In this study increasing density up to 25,973 plant ha^{-1} increase yield. Corm number continued to increase above this density. As a result mean corm weight per plant decrease with increasing population density. Corm number and weight are important in taro production. The former affect the multiplication rate of the crop the later is yield. Growers make decision on the bases of weight of corm > 250g for consumption; those < 250g for planting (Gendua *et al.*, 2000) [13]. In the present study, maximum yield was attained at 25,973 plants ha^{-1}. At this density, both economical (marketable) and unmarketable that can be used for planting are achieved. Further increase in density resulted in decrease with consumable corm yield while the unmarketable portion remained unchanged. Since farmers need to ensure both high yield and used a $1/10^{th}$ of this amount for planting, both needs are attained at this density.

Summary and Conclusion

The productivity of crops in general and taro in particular in farmers' fields are affected by a number of factors such as soil fertility, size of planting material, variety, weed, suckering, type of planting material, population density (spacing) and the like. Among these factors, type of planting materials and population density have been investigated and found to influence productivity of taro in many countries. In Ethiopia, farmers who grow potatoes give less regard to optimal plant population (Endale and Gebremedehen, 2001), which seems also true for other root and tuber crops including taro. Moreover, the effect of type of planting material (corm and cormels) and population density on yield and yield components of newly released and high yielding variety Boloso-1 on the study area is not known. An experiment was conducted at from April 2017 to January 2018 with two types of planting material (corm and cormel) and four different inter-rows (35, 50, 65 and 80cm) and intra-rows (50, 70, 90 and 110cm) spacing in a split -plot design with three replications. The treatments included factorial combination of two types of planting material as main plot (corm and cormels) and sixteen plant densities as sub plot treatment. Data on vegetative and yield attributes were examined to determine the response of taro using different planting material and densities.

Upland taro is ready for harvest 8-10 months after planting. As harvest time approaches, the leaves turn yellowish and the petioles are short, usually less than 2 ft long. The corms protrude from the ground. Dasheen is ready for harvest when all or most of the cormels have become dormant; that is, when the leaves have dried. Time of maturity varies with location, varieties used, soil

The result revealed that planting material had significant ($p \leq 0.05$) effect on 50% emergence, plant height, number of leaves, number of shoot, weight of corm, dry matter percentage per plant, and marketable and total yield per hectare. Corm type of planting material recorded higher value for the parameters studied. Increasing density highly and significantly ($p \leq 0.001$) increased shoot number, LAI per plant and total, marketable and unmarketable yield per hectare while, it is significantly decreased number of corm and weight of corm per plant. Type of planting material and spacing interaction had a significant ($p \leq 0.001$) on total and marketable yield per hectare with their yield at 25,973 plants ha^{-1} (35cm x 110cm) for both type of planting material. In this study corm yield per unit area were maximized at higher densities. However, average shoot number, number of corm and weight of corm per plant were maximized at lower densities. The result of this study revealed that for both marketable and unmarketable yield plant population density of 25,973 plants ha^{-1} is most convenient.

Taro Benefits

Taro Root also helps with irritability, lowers blood pressure, prevents cell damage, helps to protect from colds and flues, helps with skin rashes, nausea, and also helps to regulate cholesterol, builds strong bones, and supports thyroid function.

Great Flavor and Beautiful Plants- Taro Roots and leaves must be cooked, and the roots have a nutty flavor that’s wonderful, and the leaves can also be cooked. and some say they tastes like cabbage. The large leaves are called elephant ears and make wonderful ornamental plants... they are very beautiful. Taro Roots can be used in all kinds of dishes from curries, to eating them boiled and mashed just like potatoes, and in just about any recipe that you use potatoes. Taro can also be roasted, boiled, steamed, fried for chips, made into cakes, purred, and just about any other way you want to use them... and you can find Taro Chips at your local super market. You can buy Taro Roots at your local super market, at Asian markets, Latin American markets, and other ethnic stores.

(http://www.spc.int/lrd/index.php?option=com_content&view=article&id=613&Itemid=370).

In summary, taro production should be supported by fertilizer application through repeated and different location studies or experiments on application of NP fertilizer. The strategy for maximizing crop yield by supplying fertilizers to soils requires knowledge of the inherent nutrient status and nature of nutrient release of the soils, and the nutrient uptake potential of the crop.

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