Effect of Seed Rate, Planting Method and Location on the Yield of *Corchorus olitorius* in the Greater Accra Region

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Abstract

***Corchorus olitorius* is a traditional vegetable in Ghana. It is relatively affordable and has become a popular alternative to okra (*Abelmoschus esculentus)*, especially when okra becomes expensive in the market. However, there is limited information on its recommended agronomic practices such as seed rate and planting method. Therefore, there is the need to develop appropriate agronomic practices for the optimal production of *Corchorus olitorius*. A 2 x 2 x 4 factorial experiment was carried out to determine the effect of location, planting method and seed rate on the yield of *Corchorus olitorius*. There were three factors, that is, location (University of Ghana Research Farm and Amrahia), planting methods (broadcasting and drilling) and seed rates (0.5 gm^{-2}, 0.6 gm^{-2}, 0.7 gm^{-2} and 0.8 gm^{2}). Data was collected on fresh and dry weight of leaves, stems and branches and roots per area. The data was subjected to analysis of variance (ANOVA) using GenStat statistical software (12th Edition) to determine the effect of various treatments on yield. Tukey's test was used to separate significant means at 5% probability. The result of the study showed that generally, there was a significant increase ($p < 0.05$) in fresh and dry yield of *Corchorus olitorius* with higher seed rates, the drilling method and at the location with a higher soil nitrogen content. The highest fresh yield of leaves of 1989.1 gm^{-2}(19.89 tha^{-1}) was produced by drilling *Corchorus olitorius* seeds at a seed rate of 0.8 gm^{-2}at the University of Ghana Research Farm. It is therefore recommended that *Corchorus olitorius* is drilled at 0.8 gm^{-2} for a higher return.**

Keywords: *Corchorus olitorius*, planting method, seed rate, location, yield

Introduction

Corchorus olitorius is an erect, annual herb, up to 2 to 4 m tall and usually strongly branched (Fondio and Grubben, 2011). Some authors categorize *Corchorus olitorius* into the *Malvaceae* family (Nwangburuka *et al*., 2012; Nyadanu *et al*., 2016), whilst others categorize it into the Tiliaceae family (Aluko *et al*., 2014; Azadbakht *et al.*, 2015; Naim *et al.*, 2015; Amoatey *et al.*, 2018). Evaluating different authors' proposals about the origin of *Corchorus olitorius* leads to different conclusions. Some authors claim the continent of origin to be Africa, whilst others insist that it originated from Asia. India or the Indo-Burmese area are proposed to be the centre of origin by some authors according to Osawaru *et al.* (2013). However, Osawaru *et al.* (2013) named Africa as the original source, due to the occurrence of a higher genetic heterogeneity of the plant's population there. According to Raemaekers (2001), *Corchorus olitorius* was first domesticated and grown in Indo-China, whereas tropical Africa is considered to be a secondary area of production. According to Aluko *et al.* (2014), the origin of *Corchorus olitorius* was South China and then an introduction to India and Pakistan occurred. Even so, they noted that the plant occurred in the wild in numerous areas of India, China, Australia and Africa; especially in south-western Nigeria. Comparably, Islam (2013) postulated that *Corchorus olitorius* is indigenous to tropical Africa and Asia, and then extended to Australia, South America and some parts of Europe. Sato and Narimatsu (2000) reported that the herb was brought to Japan from Egypt.

Corchorus olitorius is morphologically diverse. Agro-morphological characterization of *Corchorus olitorius* in Benin revealed that there are six classes of cultivars (Adebo *et al.,* 2015). Other known cultivars includes the Nigerian cultivar "Amugbadu" and "Oniyaya", and the Cameroonian cultivar "Ewondo" (Raemaekers, 2001; Grubben and Denton, 2004). Varietal breeding in *Corchorus olitorius* for jute production has resulted in several high fibre yielding varieties (Mahapatra *et al.*, 2009).The farmers in the Greater Accra Region of Ghana cultivate two varieties, namely the "Mante variety" and the "Togo variety". The "Mante variety" supposedly originated from a town called Mante in the Brong-Ahafo Region, whilst the "Togo variety" is believed to have originated from Togo. The two varieties clearly show a difference in leaf morphology.

Grubben and Denton (2004) argued that *Corchorus olitorius* achieves maximum performance under high temperatures and humidity, yet, it is susceptible to drought and water-logging and cannot thrive in shady conditions. It is also prone to stem and root rot when exposed to excessive moisture (Amoatey *et al.*, 2018). Young *Corchorus olitorius* seedlings tend to wilt and flower prematurely when subjected to low humidity (≤ 19%) and soil moisture (< 20%). The critical water potential for germination of *Corchorus olitorius* is about-0.3 Mpa, and it required 18 hours for germination to occur (Palit and Bhattacharya, 1981). The optimal temperature for *Corchorus olitorius* is 25 °C to 32 °C, it cannot perform at temperatures beneath 15 °C and it is sensitive to periods of long daylight (Fondio and Grubben, 2011). Thus, a change in day length can have an impact on leaf, fruit and seed development (Amoatey *et al.*, 2018). A day length of 12.5 hours promotes vegetative growth, whilst a day length of 11.5 hours or less enhanced flower, fruit and seed production (Fondio and Grubben, 2011). *Corchorus olitorius* is tolerant to a pH of 4.5 to 8.2 (The Department of Agriculture, Forestry and Fisheries of the Republic of South Africa, 2012) and prefers alluvial soils, or those with lots of organic matter and a good water-retaining capacity (Raemaekers, 2001).

Corchorus olitorius plants grow very fast after germination, seedling growth is rapid, leaf formation, however, is generally slow at the beginning (Amoatey *et al*., 2018). During short days, flowering begins about 4 weeks after the seedlings have emerged and continues for 4 to 8weeks, depending on the variety and environment. The fruits mature after about 3 to 4 months, then the leaves senescence and death of the entire organism follows shortly (Grubben and Denton, 2004). Khandakar and van der Vossen (2016) claimed that first flower appearance occurs within a period of 82 to 154 days after sowing, depending on the cultivar. Also, a hard seed coat causes dormancy in *Corchorus olitorius* seeds (Chauhan and Johnson, 2008). For an optimum yield, Fondio and Grubben (2011) recommended the use of organic manure at a rate of around 20 tha^{-1}, a basal application of NPK (e.g. 15-15-15 at 400 $kgha^{-1}$) and a side dressing with nitrogen.

Corchorus olitorius is affected by many pests including spidermites, grasshoppers, caterpillars, army-worms, flea beetles, red spider mites and root-knot nematodes (*Meloidogyne* spp.). The diseases of *Corchorus olitorius* includes damping-off caused by *Rhizoctonia*, *Pythium* or *Phytophthora* spp. in nurseries and stem rot caused by *Sclerotium rolfsii*, which occurs frequently during the dry season in South Africa (Raemaekers, 2001; The Department of

Agriculture, Forestry and Fisheries of the Republic of South Africa, 2012).

Harvesting of the young shoots commences six weeks after sowing and may extend over another five weeks (Raemaekers, 2001)). It is recommended that the first harvest can be made just before fruiting, 4 to 6 weeks after transplanting or 30 to 60 days after planting. Flower development of the plants slows down when they are cut regularly, which allows for shoots to be harvested over a longer period. A harvest can be made every 2 to 3 weeks, with a maximum of 2 to 8 harvests. The entire crop can also be harvested at once when it has grown to 30 to 40 cm, 3 to 5 weeks after emergence (Fondio and Grubben, 2011). *Corchorus olitorius* leaves per 100 g are composed of 80.4 g water, 243 kJ (58 kcal) energy, 4.5 g protein, 0.3 g fat, 12.4 g carbohydrate, 2.0 g fibre, 360 mg calcium, 122 mg phosphorus, 7.2 mg iron, 6410ug ß-carotene, 0.15 mg thiamin, 0.53 mg riboflavin, 1.2 mg niacin and 80 mg ascorbic acid (Leung *et al.*, 1968).

Corchorus olitorius is the foremost leafy vegetable in Cote d'Ivoire, Benin, Nigeria, Cameroon, Sudan, Kenya, Uganda and Zimbabwe and is cultivated secondarily in the Caribbean, Brazil, India, Bangladesh, China, Japan, Egypt and the Middle East (Grubben and Denton, 2004). It is a traditional vegetable in Ghana and is used for food and medicine (Nyadanu *et al.*, 2016). When cooked, *Corchorus olitorius* leaves become mucilaginous, similar to okra (*Abelmoschus esculentus*). A lot of Ghanaians enjoy this sliminess in their local dishes. It is also relatively affordable and has become a popular alternative to okra, especially when okra becomes expensive in the market. Nonetheless, many Ghanaians prefer to purchase foreign vegetables like cabbage, lettuce, cucumbers and carrots, although their prices are relatively higher (Darkwa and Darkwa, 2013; Nyadanu*et al.*, 2016), because they believe them to be superior and seem to be uninformed about local vegetables' high nutrient contents and health benefits. *Corchorus olitorius* is one of the cheapest sources of minerals and vitamins, being rich in folic acid used to prevent folate deficiency in pregnant women in Africa (Salami and Olawole, 2011). As such, it could be recommended to pregnant women by health care professionals. Zeghichi *et al.* (2003) reported that *Corchorus olitorius* is being added as an ingredient to skin and hair beauty products, due to its proposed anti-aging and rejuvenating qualities. An evaluation made by Taiwo *et al.* (2016) disclosed that *Corchorus olitorius* is a major ingredient in locally prepared anti-cancer medicine in Nigeria. Therefore, research to assess the polyphenolic compounds with anti-cancer potential from *Corchorus olitorius* was undertaken that confirmed its anti-cancer qualities and prospective use as a natural alternative to orthodox cancer therapy. In Ghana, the herb is used to treat fever, waist pain, stomach problems, boils, loss of appetite (Nyadanu *et al.*, 2016) and to increase sexual stamina in men. Therefore, Nyadanu *et al.* (2016) stressed the promotion, consumption and genetic upgrading of the crop.

Corchorus olitorius is mostly cultivated as a rain-fed crop and is not given much attention (Grubbenand Denton, 2004). Therefore, prices are higher during the dry season than the rainy season (Amoatey *et al.*, 2018). As of 2007, van Rensburg *et al.* (2007) reported that in South Africa, *Corchorus olitorius* was not cultivated but collected from the wild. Yet, they envisioned the plants prospective as a domesticated crop. Masekoa *et al.* (2015) added that in South Africa, the plant is generally seen as a wild species and has not really been considered for large-scale commercialization. Emongor *et al.* (2004) reported that in Botswana, only few farmers produce the crop commercially, and that it is rather collected from the wild. Velempini *et al.* (2003) listed poor seed germination and negative stigmatization that comes with the consumption of traditional vegetables as the major constraint to the commercial production of *Corchorus olitorius* in Botswana. In a study in Ghana, Nyadanu *et al.* (2016) found the major constraints of *Corchorus olitorius* production to be a lack of agronomic research on the crop, lack of improved cultivars, lack of adequate planting distances, lack of adequate fertilizer dosages, lack of knowledge about effects of harvesting methods and high post-harvest losses.

Despite the fact that *Corchorus olitorius* is enjoying much popularity amongst many different ethnic groups and nations, statistical data on its production, trade and marketing trends are lacking. Similarly, Fondio and Grubben (2011) reported that even though powdered *Corchorus olitorius* is internationally traded under the Arabic label "meloukhia", its economic contribution is totally ignored and significant data remains unrecorded. There are also no *Corchorus olitorius* production figures for Ghana or import figures from Togo.

Corchorus olitorius is propagated by seed and broadcasting is the most common method of cultivation (Amoatey*et al.*, 2018). Direct seeding is used when a sufficient quantity of seed is available, there is not enough labour and during the dry season when there is no danger of flooding (Palada and Chang, 2003). Raemaekers (2001) recommended a seed rate of 5 to 8 $kgha^{-1}$ and a hot water seed treatment to break dormancy. Palada and Chang (2003) recommended a seed rate of 0.5 to 2.5 gm^{-2} depending on viability and seed size, steeping the seeds in just-boiled water for 10 seconds and drying them overnight. Grubben and Denton (2004) recommended that the seeds should be drilled in rows 20 to 30 cm apart.

Little agronomic research has been done on the crop in Ghana, thus there are no recommendations for seed rate and planting method. The small-scale farmers in the Greater Accra Region broadcast and do not use any recommended seed rate for their *Corchorus olitorius* crop. A good seed rate and planting method are, however, important for economic production. Therefore, the objective of this study was to determine the effect of planting method, seed rate and location on the yield of *Corchorus olitorius*.

Materials and Methods

Study site

The experiment was carried out in the Greater Accra Region at the University of Ghana Research Farm at Legon from 27th April to 8th June, 2019 and at Amrahia in the Adenta Municipality from 22nd May to 3rd July, 2019.The University Farm was located at latitude 5° 39‘‘N and longitude 0° 11‘‘ W. The previous crop grown at the trial site was soyabean (*Glycine max*) for one season. During the experiment, 13 rainy days occurred with a total rainfall of 275.4 mm (Table 1). The experimental site at Amrahia had a GPS of latitude 5.77963 and longitude -0.14277, had been fallow for three years and experienced 16 rainy days, with a total rainfall of 435.9 mm, during the experimental period (Table 1). At both experimental sites, mean day length was about 12 hours, mean temperatures ranged from 23 °C to 25 °Cminimum and 28°C to 32 °C maximum. Mean relative humidity at Amrahia was 47 % to 48 % minimum and 86 % to 88 % maximum, whilst that at the Research Farm was 45 % to 47 % minimum and 80 % to 85 % maximum (Table 1). The soil textures of both trial sites were sandy loam (Table 2). Their soils contained 0.6 % and 0.1 % total nitrogen, 10.2 mg/kg and 8.3 mg/kg available phosphorus, 0.6 cmol/kg and 0.5cmol/kg available potassium, 1.6 % and 2.2 % organic carbon, 144.3 µS/cm and 137.8 µS/cm electrical conductivity and pH 5.3 and pH 5.8 for the University of Ghana Research Farm at Legon and Amrahia, respectively (Table 2).

Table 1. Climatic data during the study period at the experimental sites from April, 2019 to July 2019

Experimental Site	Month	Number of rainy days	Total rainfall (mm)	Mean day length (h)	Mean Temperature (°C)		Mean Relative Humidity (%)	
					Min.	Max.	Min.	Max.
University of Ghana Research Farm	April	3	95.5	12:14	25	32	45	80
	May	5	88.7	12:22	24	31	46	82
		5	91.2	12:26	24	30	47	85
Mrahia	May	6	160.3	12:22	25	32	47	86
	June	5	182.0	12:26	24	30	48	88
	July	5	93.6	12:24	23	28	48	86

Source: Ghana Meteorological Services Agency (2019)

Table 2. Initial chemical and physical soil properties of the experimental sites at the University of Ghana Research Farm and Amrahia.

	University of Ghana Research Farm	Amrahia
Chemical soil properties		
Total nitrogen (%)	0.6	0.1
Available phosphorus (mg/kg)	10.2	8.3
Available potassium (cmol/kg)	0.6	0.5
Organic carbon (%)	1.6	2.2
Electrical conductivity (µS/cm)	144.3	137.8
pH	5.3	5.8
Physical soil properties		
% Sand	67.84	66.20
% Silt	9.27	10.86
% Clay	23.09	18.33
Texture	sandy loam	sandy loam

Source: Department of Soil Science, University of Ghana (2019)

Source of seeds

Seeds of the "Togo variety" were purchased from small scale farmers at Ashale Botwe, in Greater Accra.

Experimental design, layout and experimental treatments

A 2 x 2 x 4 factorial treatment combination of two locations (University of Ghana Research Farm and Amrahia), two planting methods (broadcasting and drilling) and four seed rates ($0.5\ gm^{-2}$, $0.6\ gm^{-2}$, $0.7\ gm^{-2}$ and $0.8\ gm^{-2}$) was laid out in a Randomized Complete Block Design with four replications. The experimental units were 2 m × 2 m, with 1 m between plots and between blocks. *Corchorus olitorius* seeds were steeped in hot water at 100 °C for 10 seconds and allowed to dry. The seeds were then broadcast and drilled at the rates of 0.5 gm^{-2}, 0.6 gm^{-2}, 0.7 gm^{-2} and 0.8 gm^{-2}, at Amrahia and the University of Ghana Research Farm. The seeds were mixed with sand to ensure a more even spread during sowing. Due to the small size of the seeds, the planting depth was 0.5cm.

Field maintenance

The crop was fertilized by applying a 15-15-15 NPK fertilizer at a rate of 400 kg ha^{-1} by broadcasting for the broadcasting planting method, and as a side dressing along the rows for the drilling method, on the day of sowing. The plants were irrigated twice a day for the first 4 weeks and once a day for the subsequent weeks. Lambda Super 2.5 EC (lambda-cyhalothrin) was applied to the leaves of the *Corchorus olitorious* plants, when they were 14 days old, in order to control chewing and piercing insects. This was repeated at a 14 day interval at a rate of 5 ml per 15 L knapsack sprayer. Weeding was performed manually through hoeing and hand pulling once every week.

Data collection

A 1 m^2 destructive sampling was carried out 42 days after sowing, at which the crop is considered mature for harvesting (Raemaekers, 2001; The Department of Agriculture, Forestry and Fisheries of the Republic of South Africa, 2012), in order to determine the fresh and dry weight of leaves, stems and branches and roots per square metre and hectare. This was done within the center of the plots for the broadcasting method and the bordered rows for the drilling method. All plants within the quadrant were uprooted, for each treatment. The plants were separated into leaves, stems and branches and roots and labelled according to treatment. The weight of the individual plant parts was measured immediately with a digital weighing scale, in order to determine their fresh yield. The labelled plant parts were then put in an oven to dry at 70 °C for 3 days (72 hours). Thereafter, the dried plant parts were weighed with a digital weighing scale once more in order to determine their dry yield.

Data analysis

The collected data was subjected to an analysis of variance (ANOVA), using GenStat statistical software (12^{th} Edition), in order to determine whether there were significant differences in the means of yield among the different treatments. Tukey's method at 5% probability was used to seperate treatment means.

Results

The effect of location, planting method and seed rate on fresh and dry yield of leaves

There were significant differences ($p < 0.05$) in fresh yield of leaves amongst locations, planting methods, seed rates and the location x planting method interaction (Table 3). Fresh leaves yield ranged from the lowest of 1055.9 $gm^{-2}$for broadcasting at 0.5 gm^{-2} in Amrahia to the highest of1989.1 gm^{-2} for drilling at 0.8 gm^{-2} at the University of Ghana Research Farm (Table 3). The University of Ghana Research Farm, the drilling method and the 0.8 gm^{-2} seed rate produced significantly ($p < 0.05$) higher yields than their counterparts (Table 3).

There were significant differences ($p < 0.05$) in dry yield of leaves amongst locations, planting methods, seed rates and the location x planting method interaction (Table 4). Dry leaves yield ranged from the lowest of 595.6gm^{-2} for broadcasting at 0.5 gm^{-2} in Amrahia to the highest of1117.5 gm^{-2} for drilling at 0.7 gm^{-2} at the University of Ghana Research Farm (Table 4). The University of Ghana Research Farm and the drilling method produced significantly ($p < 0.05$) higher yields than their counterparts (Table 4).

Table 3. The effect of location, planting method and seed rate on fresh weight of leaves (g and t) per square metre and hectare of *Corchorus olitorius* 42 days after sowing.

Fresh yield of leaves (gm^{-2}) [tha^{-1}]							
L	PM	SR				L x PM Mean	L mean
		0.5 gm^{-2}	0.6 gm^{-2}	0.7 gm^{-2}	0.8 gm^{-2}		
UG	BR	1329.2 (13.29)	1468.9 (14.69)	1568.6 (15.69)	1647.5 (16.48)	1503.5 b (15.06)	1683.1 a (16.83)
	DR	1647.2 (16.47)	1880.8 (18.81)	1933.9 (19.34)	1989.1 (19.89)	1862.8 c (18.63)	
L x SR Mean		1488.2 (14.88)	1674.8 (16.75)	1751.3 (17.51)	1818.3 (18.18)		
AM	BR	1055.9 (10.56)	1189.2 (11.89)	1232.0 (12.32)	1325.7 (13.26)	1200.7 a (12.01)	1327.4 b (13.27)
	Dr	1327.8 (13.28)	1455.3 (14.55)	1475.3 (14.75)	1558.1 (15.58)	1454.1 b (14.54)	
L x SR Mean		1191.9 (11.92)	1322.3 (13.22)	1353.7 (13.54)	1441.9 (14.42)		
SR Mean		1340a (13.40)	1499b (14.99)	1552b (15.52)	1630c (16.30)		
						PM Mean	
PM x SR Mean	Br	1192.6 (11.93)	1329.0 (13.29)	1400.3 (14.00)	1486.6 (14.87)	1352.1 a (13.52)	
	Dr	1487.5 (14.88)	1668.0 (16.68)	1704.6 (17.05)	1773.6 (17.74)	1658.4 b (16.58)	

*Weight in brackets is in tonnes per hectare. [a]Means followed by different letter(s) within a row and column are significant at 5% level of probability using Tukey's Multiple Comparison Test. L= Location, PM= Planting Method, SR= Seed Rate, BR= Broadcasting, DR= Drilling, UG= University of Ghana Research Farm and AM= Amrahia

Table 4. The effect of location, planting method and seed rate on dry weight of leaves (g and t) per square metre and hectare of *Corchorus olitorius* 42 days after sowing.

Dry yield of leaves (gm^{-2}) [tha^{-1}]							
L	PM	SR				L x PM Mean	L mean
		0.5 gm^{-2}	0.6 gm^{-2}	0.7 gm^{-2}	0.8 gm^{-2}		
G	BR	714.3 (7.14)	764.0 (7.64)	809.7 (8.10)	833.9 (8.34)	780.5 b (7.81)	912.9 a (9.13)
	DR	931.7 (9.32)	1052.1 (10.52)	1117.5 (11.18)	1080.1 (10.80)	1045.4 c (10.45)	
L x SR Mean		823.0 (8.23)	908.1 (9.08)	963.6 (9.64)	957.0 (9.57)		
AM	BR	595.6 (5.96)	688.6 (6.89)	678.2 (6.78)	721.4 (7.21)	671.0 a (6.71)	741.3 b (7.41)
	Dr	721.3 (7.21)	834.8 (8.35)	837.3 (8.37)	853.2 (8.53)	811.7 b (8.12)	
L x SR Mean		658.5 (6.59)	761.7 (7.62	757.7 (7.58)	787.3 (7.87)		
SR Mean		740.8 a (7.41)	834.9 b (8.35)	860.7 b (8.61)	872.1 b (8.72)		
						PM Mean	
PM x SR Mean	Br	655.0 (6.55)	726.3 (7.26)	743.9 (7.44)	777.6 (7.78)	725.7 a (7.26)	
	Dr	826.5 (8.27)	943.5 (9.44)	977.4 (9.77)	966.6 (9.670	928.5 b (9.29)	

*Weight in brackets is in tonnes per hectare. [a]Means followed by different letter(s) within a row and column are significant at 5% level of probability using Tukey's Multiple Comparison Test. L= Location, PM= Planting Method, SR= Seed Rate, BR= Broadcasting, DR= Drilling, UG= University of Ghana Research Farm and AM= Amrahia

The effect of location, planting method and seed rate on fresh and dry yield of stems and branches

There were significant differences ($p < 0.05$) in fresh yield of stems and branches amongst locations, planting methods and seed rates but not their interactions (Table 5). Fresh stems and branches yield ranged from the lowest of 1175.0gm^{-2} for broadcasting at 0.5 gm^{-2} in Amrahia to the highest of 2302.0gm^{-2} for drilling at 0.8 gm^{-2} at the University of Ghana Research Farm (Table 5). The University of Ghana Research Farm, the drilling method and the 0.8 gm^{-2} seed rate produced significantly ($p < 0.05$) higher yields than their counterparts (Table 5).

There were significant differences ($p < 0.05$) in dry yield of stems and branches amongst locations, planting methods and seed rates but not their interactions (Table 6). Dry stems and branches yield ranged from the lowest of 419.7 gm^{-2} for broadcasting at 0.5 gm^{-2} in Amrahia to the highest of 792.0gm^{-2} for drilling at 0.8 gm^{-2} at the University of Ghana Research Farm (Table 6). The University of Ghana Research Farm and the drilling method produced significantly ($p < 0.05$) higher yields than their counterparts (Table 6).

Table 5. The effect of location, planting method and seed rate on fresh weight of stems and branches (g and t) per square metre and hectare of *Corchorus olitorius* 42 days after sowing.

Fresh yield of stems and branches (gm^{-2}) [tha^{-1}]							
L	PM	SR				L x PM Mean	L mean
		0.5 gm^{-2}	0.6 gm^{-2}	0.7 gm^{-2}	0.8 gm^{-2}		
UG	BR	1490 (14.90)	1648 (16.48)	1756 (17.56)	1857 (18.57)	1688 (16.88)	1913 a (19.13)
	DR	1880 (18.80)	2154 (21.54)	2220 (22.20)	2302 (23.02)	2139 (21.39)	
L x SR Mean		1685 (16.85)	1901 (19.01)	1988 (19.88)	2080 (20.80)		
AM	BR	1175 (11.75)	1350 (13.50)	1443 (14.43)	1556 (15.56)	1381 (13.81)	1583 b (15.83)
	Dr	1578 (15.78)	1755 (17.55)	1833 (18.33)	1972 (19.72)	1784 (17.84)	
L x SR Mean		1376 (13.76)	1552 (15.52)	1638 (16.38)	1764 (17.64)		
SR Mean		1531 a (15.31)	1727 b (17.27)	1813 b (18.13)	1922 c (19.22)		
						PM Mean	
PM x SR Mean	Br	1332 (13.32)	1499 (14.99)	1600 (16.00)	1706 (17.06)	1534 a (15.34)	
	Dr	1729 (17.29)	1954 (19.54)	2026 (20.26)	2137 (21.37)	1962 b (19.62)	

*Weight in brackets is in tonnes per hectare. [a]Means followed by different letter(s) within a row and column are significant at 5% level of probability using Tukey's Multiple Comparison Test. L= Location, PM= Planting Method, SR= Seed Rate, BR= Broadcasting, DR= Drilling, UG= University of Ghana Research Farm and AM= Amrahia

Table 6. The effect of location, planting method and seed rate on dry weight of stems and branches (g and t) per square metre and hectare of *Corchorus olitorius* 42 days after sowing.

L	PM	Dry yield of stems and branches (gm^{-2}) [tha^{-1}] SR				L x PM Mean	L mean
		0.5 gm^{-2}	0.6 gm^{-2}	0.7 gm^{-2}	0.8 gm^{-2}		
UG	BR	549.1 (5.49)	602.7 (6.03)	629.3 (6.29)	647.6 (6.48)	607.2 (6.10)	679.3 a (6.79)
	DR	675.5 (6.76)	763.8 (7.64)	774.2 (7.74)	792.0 (7.92)	751.4 (7.51)	
L x SR Mean		612.3 (6.12)	683.2 (6.83)	701.7 (7.02)	719.8 (7.20)		
AM	BR	419.7 (4.20)	480.6 (4.81)	512.6 (5.13)	542.6 (5.43)	488.9 (4.89)	548.6 b (5.49)
	DR	544.0 (5.44)	606.4 (6.06)	627.4 (6.27)	655.4 (6.55)	608.3 (6.08)	
L x SR Mean		481.8 (4.82)	543.5 (5.44)	570.0 (5.70)	599.0 (5.99)		
SR Mean		547.1 a (5.47)	613.4 b (6.13)	635.9 bc (6.36)	659.4 c (6.59)		
						PM Mean	
PM x SR Mean	BR	484.4 (4.84)	541.7 (5.42)	570.9 (5.71)	595.1 (5.95)	548.0 a (5.48)	
	DR	609.8 (6.10)	685.1 (6.85)	700.8 (7.01)	723.7 (7.24)	679.8 b (6.80)	

*Weight in brackets is in tonnes per hectare. [a]Means followed by different letter(s) within a row and column are significant at 5% level of probability using Tukey's Multiple Comparison Test. L= Location, PM= Planting Method, SR= Seed Rate, BR= Broadcasting, DR= Drilling, UG= University of Ghana Research Farm and AM= Amrahia

The effect of location, planting method and seed rate on fresh and dry yield of roots

There were significant differences ($p < 0.05$) in fresh yield of roots amongst locations, planting methods, seed rates and their interactions (Table 7). Fresh root yield ranged from the lowest of 326.7gm^{-2} for broadcasting at 0.5 gm^{-2} in Amrahia to the highest of 605.1 gm^{-2} for drilling at 0.6 gm^{-2} at the University of Ghana Research Farm (Table 7).The University of Ghana Research Farm and the drilling method produced significantly ($p < 0.05$) higher yields than their counterparts (Table 7).

There were significant differences ($p < 0.05$) in dry yield of roots amongst locations, planting methods, seed rates and their interactions, except for the location x planting method x seed rate interaction (Table 8). Dry roots yield ranged from the lowest of134.8 gm^{-2} for broadcasting at 0.5 gm^{-2} in Amrahia to the highest of 255.9 gm^{-2} for drilling at 0.6 gm^{-2} at the University of Ghana Research Farm (Table 8). The University of Ghana Research Farm, the drilling method and the 0.6 gm^{-2} seed rate produced significantly ($p < 0.05$) higher yields than their counterparts (Table 8).

Table 7. The effect of location, planting method and seed rate on fresh weight of roots (g and t) per square metre and hectare of *Corchorus olitorius* 42 days after sowing.

Fresh yield of roots (gm^{-2}) [tha^{-1}]							
L	PM	SR				L x PM Mean	L mean
		0.5 gm^{-2}	0.6 gm^{-2}	0.7 gm^{-2}	0.8 gm^{-2}		
UG	BR	426.4 cde (4.26)	459.0 de (4.60)	476.7 e (4.77)	351.4 ab (3.51)	428.4 b (4.28)	504.0 a (5.04)
	DR	548.0 f (5.48)	605.1 f (6.05)	589.3 f (5.89)	576.5 f (5.77)	579.7 c (5.80)	
L x SR Mean		487.2 e (4.87)	532.1 f (5.32)	533.0 f (5.33)	463.9 de (4.64)		
AM	BR	326.7 a (3.27)	358.1 ab (3.58)	385.9 abc (3.86)	402.1 bcd (4.02)	368.2 a (3.68)	396.5 b (3.97)
	Dr	405.8 bcd (4.06)	406.7 bcd (4.07)	432.1 cde (4.32)	454.2 de (4.54)	424.7 b (4.25)	
L x SR Mean		366.3 a (3.66)	382.4 ab (3.82)	409.0 bc (4.10)	428.2 cd (4.28)		
SR Mean		426.7 a (4.27)	457.2 bc (4.57)	471.0 c (4.71)	446.0 ab (4.46)		
						PM Mean	
PM x SR Mean	Br	376.6 a (3.77)	408.5 ab (4.09)	431.3 b (4.31)	376.7 a (3.78)	398.3 a (3.98)	
	Dr	476.9 c (4.77)	505.9 cd (5.06)	510.7 cd (5.11)	515.3 d (5.15)	502.2 b (5.02)	

*Weight in brackets is in tonnes per hectare. [a]Means followed by different letter(s) within a row and column are significant at 5% level of probability using Tukey's Multiple Comparison Test. L= Location, PM= Planting Method, SR= Seed Rate, BR= Broadcasting, DR= Drilling, UG= University of Ghana Research Farm and AM= Amrahia

Table 8. The effect of location, planting method and seed rate on dry weight (g and t) of roots per square metre and hectare of *Corchorus olitorius* 42 days after sowing

Dry yield of roots (gm^{-2}) [tha^{-1}]							
L	PM	SR				L x PM Mean	L mean
		0.5 gm^{-2}	0.6 gm^{-2}	0.7 gm^{-2}	0.8 gm^{-2}		
UG	BR	186.6 (1.87)	194.0 (1.94)	184.1 (1.84)	174.5 (1.75)	184.8 b (1.85)	210.9 a (2.11)
	DR	248.0 (2.48)	255.9 (2.56)	234.1 (2.34)	209.6 (2.10)	236.9 c (2.37)	
L x SR Mean		217.3 d (2.17)	225.0 d (2.25)	209.1 d (2.09)	192.1 c (1.92)		
AM	BR	134.8 (1.35)	151.2 (1.51)	150.7 (1.51)	140.6 (1.41)	144.3 a (1.44)	163.1 b (1.63)
	DR	179.3 (1.79)	196.8 (1.97)	178.5 (1.79)	173.0 (1.73)	181.9 b (1.82)	
L x SR Mean		157.1 a (1.57)	174.0 b (1.74)	164.6 ab (1.65)	156.8 a (1.57)		
SR Mean		187.2 b (1.87)	199.5 c (2.00)	186.8 b (1.87)	174.4 a (1.74)		
						PM Mean	
PM x SR Mean	BR	160.7 a (1.61)	172.6 a (1.73)	167.4 a (1.67)	157.5 a (1.58)	164.6 a (1.65)	
	DR	213.7 cd (2.14)	226.4 d (2.26)	206.3 bc (2.06)	191.3 b (1.91)	209.4 b (2.09)	

*Weight in brackets is in tonnes per hectare. [a]Means followed by different letter(s) within a row and column are significant at 5% level of probability using Tukey's Multiple Comparison Test. L= Location, PM= Planting Method, SR= Seed Rate, BR= Broadcasting, DR= Drilling, UG= University of Ghana Research Farm and AM= Amrahia

Discussion

This study showed that drilling of *Corchorus olitorius* seeds resulted in significantly ($p < 0.05$) higher fresh and dry yield of leaves, stems and branches and roots compared with broadcasting. This is probably so, because drilling resulted in a more uniform alignment of the plants, which made cultural practices like weeding, irrigation, fertilizer and insecticide application more efficient to carry out in contrast to the broadcasting method. Additionally, drilling of the seeds created walking paths, which protected the plants from being trampled on during the above-mentioned management practices. The uniform alignment of plants could have reduced the competition for sunlight, thus allowing for better photosynthesis to occur, as well as ensuring a more uniform provision of soil nutrients with less competition. Better spraying coverage with insecticides would have also resulted in better protection from insect pests. Therefore, it can be concluded that the drilled seedlings had better access to growth resources, especially irrigation water since temperatures were very high, leading to higher biomass accumulation; and were better protected from physical damage. These findings are in line with those of Caliskan *et al.* (2004) and Soomro (2009), who also obtained higher yields with drilled sesame (*Sesamum indicum*) and wheat (*Triticum aestivum*) seeds, respectively, compared to their broadcasted counterparts.

Similarly, cultivation at the University of Ghana Research Farm resulted in significantly ($p < 0.05$) higher fresh and dry yield of leaves, stems and branches and roots of *Corchorus olitorius* than cultivation at Amrahia. Soil texture was the same at both trial locations, i.e.sandy loam (Table 1). Mean day length, temperature, relative humidity and pH were quite similar as well (Table 1 and 2). Even though number of rainy days and amount of rainfall varied slightly (Table 2), the crops were irrigated throughout the experiment. However, the soil analysis showed that the University of Ghana Research Farm plot had a higher nitrogen content than that at Amrahia (0.6 and 0.1 % N, respectively). This could have been the result of the previous crop having been soyabean, which has the ability to fix atmospheric nitrogen through symbiotic interactions with rhizobia in the soil. This explanation agrees with the study of Rutto *et al.* (2018), which found that *Corchorus olitorius* yield increased with higher concentrations of nitrogen fertilizer application to the soil.Thus, it can be concluded that the soil conditions at the Research Farm were more favourable for the growth of *Corchorus olitorius* than its counterpart at Amrahia. A similar finding was presented by Tuttolomondo *et al.* (2020), who found that climatic and soil conditions of different environmental locations can have an effect on the growth and yield of the same variety of upland cotton, planted in the same season.

Generally, there was a significantly ($p < 0.05$) increase in fresh and dry yield of leaves and stems and branches of *Corchorus olitorius* with higher seed rates. Makinde *et al.* (2007) and Maseko *et al.* (2015) found that more intra-population competition amongst *Corchorus olitorius* seedlings in higher seed rates, reduced growth. However, it can be speculated that in this study, higher seed rates increased the number of 9 plants per unit area, thus increasing yield cumulatively, which conforms with the results obtained by Rashwan (2011); Azadbakht *et al.* (2015); Law-Ogbomo and Osaigbovo (2016), who experienced an increase in yield of *Corchorus olitorius* with increased plant populations.

Conclusions and Recommendations

The study was conducted to determine the effect of location, planting methods and seed rates on the yield of *Corchorus olitorius*. The results showed that the experiment conducted at the University of Ghana Research farm produced higher yields of leaves, stems and branches and roots than that conducted at Amrahia, probably due to a higher nitrogen soil content, which promoted biomass production, since *Corchorus olitorius* is a nitrogen loving plant. Drilling caused higher yields of leaves, stems and branches and roots than its broadcasting counterpart, because it caused a more uniform plant stand, which allowed the *Corchorus olitorius* plants to have better access to growth resources, like water, nutrients and sunlight and offered better protection against physical damage. Generally, higher seed rates produced higher yields of leaves and stems and branches than their lower counterparts due to an increase in number of plants per unit area. It is therefore recommended that *Corchorus olitorius* is drilled at 0.8 gm^{-2} for a higher return. Additionally, it is recommended that future research should be carried out on the effect of harvesting on the yield of *Corchorus olitorius*, since in Ghana it is grown as a ratoon crop.

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