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Full Length Research Paper

Influence of root and shoot pruning on field establishment and growth of overgrown cashew (*Anacardium occidentale* L.) seedlings

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Delayed planting of cashew seedlings coupled with the erratic weather conditions in Ghana has often led to high transplant mortality of over grown cashew seedlings. This experiment was carried out in the Guinea savanna zone of Northern Ghana to study the effect of root and shoot pruning on the survival and field performance of overgrown (4 to 7 months old) cashew seedlings. The experiment was laid out in a randomized complete block design with four replicates. Data were collected on percentage survival, plant growth and plant canopy characteristics after planting in the field. Plant survival was significantly ($P < 0.05$) improved when seedling leaves were halved with seedlings of between 4 and 7 months old having 84 to 95% survival. Seedlings with leaves halved and roots pruned before transplanting also established better with 83 to 86% survival. However, survival was lower (mean of 58.5 and 68.9%) with respect to treatments where seedling were defoliated and or roots pruned before transplanting. Growth of cashew plants was also significantly ($P < 0.05$) affected by some of the treatments. Seedlings defoliated with roots pruned before transplanting tended to produce shorter plants with smaller stems compared with the other treatments. Height of 4 to 7 months old transplants were between 61.7 and 62.4 cm and girth 17.7 and 17.9 mm. Plant canopy area, percentage light interception and leaf area index were not significantly ($P > 0.05$) affected by the treatments after 24 months in the field. We conclude that, establishment of overgrown cashew seedlings can be improved by pruning some of the seedling roots or by halving the leaves before transplanting.

Key words: Cashew, root and shoot pruning, field establishment, seedling age.

INTRODUCTION

Cashew (*Anacardium occidentale* L) is one of the most important economic tree crops cultivated in many tropical countries, including Ghana. World production is estimated at over 4 million metric tons with Vietnam, Nigeria, India, Côte d'Ivoire, Benin, Philippines, Guinea Bissau, Tanzania, Indonesia and Brazil being the major producing countries (FAO-STAT, 2015). In Ghana, cashew cultivation is predominantly a small holder

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venture, operated by about 6,500 farmers (Anchirinah et al., 2006). The Ministry of Food and Agriculture estimated the total land area under cashew cultivation at 18,000 ha in 2000 (Anon, 2005). With the growing interest for cultivation of the crop in the country, total land under cultivation is expected to increase to 100,000 ha by the year 2020 (CDP, 2000). A major constraint to the expansion of cashew cultivation in the country however, is the difficulty associated with establishment of the crop. There is often high mortality of plants after transplanting.

Cashew farms are either established by planting seeds at stake or with nursery raised seedlings. However, the use of seedlings is recommended for establishing cashew farms because of its advantages. These advantages include; higher germination percentage, higher efficiency because there is no wastage of seeds and a better selection of vigorous seedlings can be made for planting. In spite of the advantages, planting with seedlings has often led to great losses especially where seedlings are of more than three months old are transplanted. This has been attributed to the shock at transplanting probably due to faulty planting practices (Deckers et al., 2001). Root damage during planting has been reported as one of the main causes of plant mortality in transplanting cashew seedlings (Adenikinju, 1996). Tree crops like cashew are characterized by a strong taproot. When grown in a container for longer period, the development of the taproot becomes constricted, and somehow it emerges from the bottom of the container and grows into the soil beneath. In such instances, the tap root breaks off and the root is damaged during lifting and transporting of the seedlings for planting. Root damage also causes an imbalance between the root system and canopy, and seedlings with larger canopy suffer more than smaller ones (Hassan and Rao, 1957). Although cashew seedlings are best transplanted two to three months after sowing (Opoku-Ameyaw et al., 2007; Hammed et al., 2012), observations from cashew nurseries in Ghana indicate that large numbers of seedlings are discarded after 3 months as they are considered unsuitable for planting. Taking into consideration costs involved in raising the seedlings and nursery care discarding the seedlings may not be an attractive option and there may be other possible ways of improving the transplanting success of cashew seedlings more than three months old.

Some studies have suggested that keeping a proper balance between the root system and plant canopy is necessary for increased survival of older seedlings (Castle, 1983; Watson, 1985). It may be possible to improve establishment success of old cashew seedlings if the root and leaf canopy are manipulated to provide a balanced root to shoot ratio. In some studies, the techniques of root and top/shoot pruning have been employed to improve survival of some tree species (Geisler and Ferree, 1984; Zaczek and Steiner, 2011; Sung-Joon et al., 2013). Root pruning prior to planting has been reported to stimulate root growth and root fibrosity which is of benefit to out-planting survival (Andersen et al., 2000). Top or shoot pruning is also essential in keeping a balanced root-to-shoot ratio. Top pruning is normally done with the intention of reducing transpiration and thus improve seedling survival under adverse conditions (Larson, 1975; McKay, 1997). Imposing root and shoot pruning treatments on overgrown cashew seedlings may improve establishment success in the field. The objective of this study was to determine the influence shoot and root pruning on survival and field performance of overgrown cashew seedlings.

MATERIALS AND METHODS

The experiment was carried out between 2010 and 2012 at the Cocoa Research Institute of Ghana's substation at Bole (9° 01' N, 2° 29' W, altitude 309 m above sea level) in the Guinea Savannah Zone of Northern Ghana. The station has a mean annual rainfall of 1087 mm and temperature of 26.1°C (Osei-Amaning, 1996). Climatic data (mean monthly rainfall (mm) and temperature (°C) for the study periods are presented in Table 1. The soils are mainly Ferric Luvisols with smaller areas of Eutric Regosols and Lithosols (FAO-UNESCO, 1977).

Polythene bags of size 25 cm × 18cm and 0.80 mm thickness, filled with top soil and provided with drainage holes at the bottom were used in raising the seedlings for planting. The polythene bags were arranged on 1.85 mm thickness polythene sheets to prevent the growth of the roots into the soil beneath. Cashew seeds were sown in the nursery to obtain seedlings of ages 3, 4, 5, 6 and 7 months at the time of transplanting. The 4 to 7 months old seedlings were classified as overgrown since cashew is best transplanted 2 to 3 months after sowing (Opoku-Ameyaw et al., 2007). The root and shoot pruning treatments were imposed on the 4 to 7 months old seedlings with the 3 months old seedlings as control. The treatments includes; (a) halving of all seedling leaves (ALH), (b) removing all seedlings leaves /defoliation (ALS), (c) pruning of roots (PR), (d) all leaves halved and roots pruned (ALH+PR), (e) all leaves removed and roots pruned (ALS+PR), (f) transplanting without previous treatments (no treat) and (g) treatment control. Seedling leaves were halved by cutting back half of each leaf to reduce the leaf surface area. Seedlings defoliated had all leaves removed by cutting them from the stem. Pruning of the seedling roots was done by carefully removing the seedlings from the polythene bags and pruning off excess lateral and cutting back the tap root. These were done using a hand pruning shears. Transplanting was done immediately after the imposing the pre-planting treatments. The experiment was laid out in a completely randomised complete block design with four replications. Each treatment had thirty plants spaced at 4 m × 4 m which were later thinned to 8m × 8m spacing in plots measuring 24 m × 20 m.

Data collected were percentage survival, plant girth (mm), plant height (cm), canopy area (cm^2), percentage light interception and leaf area index (LAI). Plant survival was recorded 12 months after transplanting from which percentage survival was calculated using the formula %Sur = (Ns/Nt) × 100, where Ns = number of surviving plants, Nt = Total number of seedlings planted. Seedling girth was measured using a vernier calliper and plant height was recorded using a metre rule. Measurements started at planting and were repeated quarterly for 24 months. Canopy area was estimated following the methods of Dadzie et al. (2014) by computing the average of the radius of the canopy measuring from (North - South direction and East - West Direction) in the formula,

Table 1. Mean monthly rainfall (mm) and temperature (◦C) for 2010 to 2012.

Month	2010		2011		2012	
	Rainfall (mm)	Temperature (°C)	Rainfall (mm)	Temperature (°C)	Rainfall (mm)	Temperature (°C)
January	0.0	27.7	0.0	25.7	0.0	27.2
February	8.4	30.3	28.0	27.7	34.8	28.7
March	43.3	30.1	34.3	28.7	111.0	29.6
April	71.0	30.0	107.4	28.0	105.9	28.2
May	87.8	28.7	133.9	27.3	117.3	27.0
June	217.0	26.5	129.3	25.8	135.5	26.2
July	256.0	26.2	135.6	25.2	98.7	25.3
August	239.1	24.6	237.1	24.6	60.1	24.9
September	283.7	24.5	153.1	26.1	350.1	25.9
October	342.1	25.4	165.5	26.8	140.7	26.7
November	2.9	25.6	7.8	27.6	18.2	27.7
December	0.0	25.4	0.0	25.8	0.0	27.0

Source: Meteorological Data, CRIG Substation, Bole, Ghana.

Table 2. Shoot and root pruning effects on survival (%) of cashew plants transplanted at different seedling ages.

Seedling age (months)	Treatment						Mean (treatments)
	ALH	ALS	PR	ALH+PR	ALS+PR	NO treat	
3	-	-	-	-	-	97.2	97.2
4	94.5	69.5	91.7	83.3	50.0	91.7	80.1
5	88.9	72.2	77.8	86.1	55.6	88.9	78.2
6	86.1	72.2	75.0	86.1	66.7	72.2	76.4
7	86.1	58.3	75.0	83.3	58.3	66.7	71.3
Mean (seedling age)	89.7	68.9	80.7	85.6	58.5	83.3	
LSD (0.05)							
Seedling age				12.6**			
Treatment				13.1**			
Seedling age * treatment				ns			
CV (%)				13.0			

LSD = least significant difference, CV = coefficient of variation, ns = not significant, ** = significant at P < 0.001.

$лr^2$ where л = 3.142 and r = radius of canopy. Percentage light interception and LAI were measured using the hemispherical canopy photography technique through the use of hemispherical fisheye lens (AF DX fisheye-Nikkor 10.5mm; Nikon), 24 months after planting.

Data analysis was done using two-way ANOVA in randomized blocks (GenStat 11.0 for Windows, VSN International) and treatment means separated using least significant difference (LSD).

RESULTS

Plant survival

The treatments significantly (P < 0.05) influenced survival of the old cashew plants after transplanting in the field (Table 2). The average rate of survival of seedlings with their leaves halved was 89.7%. Seedlings transplanted without previous treatment had a rate of survival of 83.3%. The results showed seedlings between 4 and 7 months old at the time of transplanting established well with rate of survival ranging from 86.1 to 94.7% when leaves had been halved (ALH). Similarly survival was above 85% when seedling leaves have been halved and roots pruned (ALH+PR). Pruning of seedling root also improved survival of the old seedlings but the 4 month old seedlings survived better with 91.7% survival rate. Removing all seedling leaves and pruning roots (ALS +PR) before transplanting however gave the lowest survival rates ranging from 50.0 to 66.7% for 4 to 7 month old seedlings. With respect to seedling age at transplanting, 3 month old seedlings survived better with 97.2% survival rate.

Table 3. Shoot and root pruning effect on girth (mm) of cashew plants 24 months after transplanting.

Seedling age (months)	Treatment						Mean (treatments)
	ALH	ALS	PR	ALH+PR	ALS+PR	NO treat	
3	-	-	-	-	-	19.4	19.4
4	20.6	16.8	20.7	20.5	17.8	20.7	19.5
5	20.7	17.5	20.8	20.7	17.9	21.0	19.7
6	21.5	17.7	21.0	21.3	17.7	21.5	20.1
7	21.6	17.9	21.4	21.6	17.7	21.6	20.5
Mean (seedling age)	21.1	17.9	20.9	20.9	17.8	21.0	
LSD (0.05)							
Seedling age				ns			
Treatment				0.64**			
Seedling age * treatment				ns			
CV (%)				17.4			

LSD = least significant difference, CV = coefficient of variation, ns = not significant, ** = significant at P < 0.001.

Table 4. Shoot and root pruning effect on height (cm) of cashew plants 24 months after transplanting.

Seedling age (months)	Treatment						Mean (treatments)
	ALH	ALS	PR	ALH+PR	ALS+PR	NO treat	
3	-	-	-	-	-	66.8	66.8
4	70.6	60.3	70.6	70.4	61.7	71.2	67.5
5	70.9	61.7	71.3	70.5	61.7	71.3	67.9
6	71.6	62.2	71.4	71.4	62.5	71.6	68.4
7	71.6	62.4	71.6	71.5	62.4	71.7	68.6
Mean (seedling age)	71.1	61.6	71.2	70.9	62.1	70.5	
LSD (0.05)							
Seedling age				ns			
Treatment				4.24**			
Seedling age * treatment				ns			
CV (%)				17.0			

Plant growth

Generally plant growth was influenced by the root and shoot pruning treatment (Tables 3 and 4). Although there were significant differences (P<0.05) in plant height among treatments, some of the treatments were not statistically different from each other. However the results showed that removing all seedlings leaves (ALS) or and with roots pruned (ALS + PR) produced shorter plants with average heights of 61.6 and 62.2.1 cm, respectively. These treatments also produced plants with the smallest girth with average plant diameter of 17.9 and 17.8 mm. This may be because more time was needed for the plants to recover from the treatments imposed. Growth of plants with leaves halved or roots pruned however were not significantly different from those which were not imposed with any of the treatment. Seedling girth and height were not significantly (P>0.05) different with respect to seedling age at transplanting but growth varied with seedling age with the old seedlings being bigger and taller than the young ones.

Plant canopy area (cm^2), percentage light interception (%LI) and leaf area index (LAI)

The shoot and root pruning treatments did not significantly (P > 0.05) affect plant canopy area measured 24 months after planting (Table 5). Mean canopy area of plants of the various treatments ranged from 342.9 to 373.9 cm^2. Plants which were not imposed with any treatment before planting and those with the leaves halved before planting recorded larger mean canopy area compared with the treatments, the differences were however not significant. Again plant canopy area varied with seedling age at planting with the older plants having

Table 5. Plant canopy area (cm^2) of cashew plants measured 24 months after transplanting.

Seedling age (months)	Treatment						Mean (treatments)
	ALH	ALS	PR	ALH+PR	ALS+PR	NO treat	
3	-	-	-	-	-	361.3	361.3
4	361.6	318.9	351.8	341.7	316.8	366.2	342.8
5	369.3	350.1	363.8	363.7	347.6	360.4	359.2
6	382.0	377.1	353.2	367.9	356.6	382.8	369.9
7	386.6	388.0	373.1	366.3	354.8	398.6	377.9
Mean (seedling age)	373.7	357.4	359.4	358.8	342.9	373.9	
LSD (0.05)							
Seedling age				ns			
Treatment				ns			
Seedling age * treatment				ns			
CV (%)				29.8			

Table 6. Percentage light interception of cashew plants measured 24 months after transplanting.

Seedling age (months)	Treatment						Mean (treatments)
	ALH	ALS	PR	ALH+PR	ALS+PR	NO treat	
3						75.4	75.4
4	76.3	68.7	72.0	74.6	68.9	75.2	72.6
5	78.1	72.0	75.4	77.2	67.6	79.4	75.0
6	80.6	73.2	76.4	78.5	68.3	81.7	76.5
7	82.5	78.5	80.2	79.9	71.2	83.7	79.3
Mean (seedling age)	79.0	72.7	75.6	77.1	68.6	79.1	
LSD (0.05)							
Seedling age				ns			
Treatment				ns			
Seedling age * treatment				ns			
CV (%)				12.0			

larger canopy than the younger plants which ranged from 342.8 to 377.9 cm^2 for seedling ages 3 to 7 months old.

Percentage light interception of plants among the various treatments was also not significantly ($P > 0.05$) different (Table 6). Mean percentage light interception for the treatments ranged from 68.6 to 79.1%, with the lowest been recorded by plants with all leaves removed and roots pruned (ALS+PR) before transplanting. Seedling age also did not significantly influence percentage light interception. Again the highest interception (79.3%) was recorded amongst 7 month old seedlings and the lowest (72.4%) by 4 month old seedlings. Similarly, leaf area index (LAI) recorded was also not significantly ($P > 0.05$) affected by root and shoot pruning treatments or seedling age 24 months after planting (Table 7).

DISCUSSION

Transplanting of overgrown cashew seedlings has often led to high mortality and poor establishment of seedlings usually attributed to imbalance between the roots and the canopy of the seedlings. Therefore, proper root to shoot balance is critical for successful seedling establishment. In this study, shoot and root pruning treatments were imposed on overgrown cashew seedlings to estimate the influence of these treatments on successful field establishment. Survival of the overgrown seedlings was increased by over 85% when seedling leaves were halved (ALH) or leaves halved and roots pruned (ALH+PR) before transplanting. This improvement in survival may be attributed to the fact that cutting back the leaves reduced leaf area and consequently, water demand of the transplants (Abod and Webster, 1990), and water loss through transpiration (Castle, 1983). This enabled the plants to conserve water, contributing to overcoming transplanting stress. Pruning of seedling roots improved survival of the overgrown cashew seedlings by over 75%. It is reported that root pruning stimulates root growth and enhance fibrous root development which improves root-soil contact needed

Table 7. Leaf area index (LAI) of cashew plants measured 24 months after transplanting.

Seedling age (months)	Treatment						Mean (treatments)
	ALH	ALS	PR	ALH+PR	ALS+PR	NO treat	
3						1.20	1.20
4	1.21	1.07	1.24	1.10	1.01	1.18	1.13
5	1.18	1.41	1.14	1.14	0.90	1.15	1.15
6	1.13	1.24	1.24	1.33	1.01	1.43	1.26
7	1.42	1.14	1.23	1.38	1.08	1.48	1.30
Mean (seedling age)	1.26	1.21	1.22	1.23	1.00	1.30	
LSD (0.05)							
Seedling age				ns			
Treatment				ns			
Seedling age * treatment				ns			
CV (%)				19.9			

for adequate water and nutrient absorption for plant growth (Geisler and Ferree, 1984; Grossnickle, 2005). Thus rapid growth of new roots increased the water and nutrient absorption capability of the plants for avoiding planting stress, critical for ensuring plant survival. Earlier studies employing these techniques in the establishment of crops like apple, citrus and other trees species also reported increase in plant survival after planting (Castle, 1983; Geisler and Ferree, 1984; Struve and Joly, 1992; DesRochers and Tremblay, 2009). Farmer (1975) and Larson (1975) reported that shoot and root pruning before transplanting allows seedlings to establish roots first before transpirational demands begin which is important for reducing transplanting stress. Maintaining an appropriate water balance is critical for newly transplanted seedlings (Grossnickle, 2005) because if water uptake is less than water loss through transpiration, leaf water deficit will develop and induce stomata closure (Pallardy, 2010). Therefore initial root to shoot relationship can have direct effect on water stress after planting and subsequent plant survival (Folk and Crossnickle, 1997). Seedling establishment is also known to be dependent on the environmental condition at the time of planting (Burdett, 1990; Oppong and Opoku-Ameyaw, 2006). For this study, planting was done when rainfall distribution was high. This may have also contributed to the successful establishment of the plants. Treatments where all seedling leaves were stripped (ALS) or leaves stripped and roots pruned (ALS+PR) did not improve survival of the seedlings. This may be because less time remained for the seedlings to regenerate enough fresh leaves to start photosynthesis before the dry season. With respect to seedling age, the 3 months old seedlings recorded the highest survival rate of over 90%. This confirms the results of Adenikinju (1996) and Opoku-Ameyaw et al. (2007) in earlier studies.

Although significant differences were observed in plant growth (height and girth) among treatments, most treatments were similar in mean growth. Our experiences from the field were that, the treatments imposed initially retarded growth of the plants after transplanting. However, after a year in the field, some of the plants were able to recover in height and girth to become similar to their control counterparts. Duyea and Landis (1984) and Abod and Wester (1990) reported similar trend in earlier studies which they attributed to the altered morphological and physiological processes of plants as a result of the treatments imposed before planting. Plant canopy characteristics such as area, light interception and leaf area index were however not significantly affected by pre-planting treatments after two years in the field. It was observed that, seedlings imposed with the treatments broke bud after several weeks in the field resulting in the production of more leaves comparable to the control plants. This confirms initial observations by McCreary and Tecklin (1993) and Zaczek et al. (2011) that plant canopy growth improves after two or three growing seasons when seedling shoot or roots are pruned before transplanting. This suggests that although early plant growth may be affected when seedling shoot and roots are pruned before transplanting, plant growth may improve after two growing seasons. Seedling age in this study did not affect the growth of the plants and canopy characteristic assessed. A similar trend was reported in an earlier study by Opoku-Ameyaw et al. (2007), which showed equal growth among cashew seedlings planted at different ages after a year in the field. This may suggest that, the performance of cashew plants in the field with time after transplanting is less dependent on crop age at transplanting but more dependent on field and environmental factor (Haferkamp, 1988).

Conclusion

The results of this study have shown that overgrown

cashew seedlings can be successfully established in the field when seedling leaves are halved and roots pruned before planting. Although early plant growth may be slow, growth improves after 12 months in the field which is also important for yield production.

Conflict of interests

The authors have not declared any conflict of interests.

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