Comparative Analysis of Seasonal Effects on the Growth Performance and Yield of Potato (Solanum Tuberosum Lin.) Under Agro -Forestry System (Alley Cropping) with the Rattle Tree (Albizia Lebbeck Benth)

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Abstract
For the past decades potato production in the Jos Plateau, Nigeria had been in two seasons (wet and dry), on open field, not under alley cropping and many potato farmers lack adequate knowledge regarding the different seasonal effects which could have enabled them devised means of circumventing the negative effects. Thus, this study was carried out to assess the differences in seasonal effects on the growth and yield of potato (*Solanum tuberosum L.*) under agrisilvicultural (alley cropping) system with emphasis on the germination, growth performance, diseases attack and yield. It was a completely randomized block design consisting of five treatments and three replicates (with or without the green manure and tree rows of *A. lebbeck*) for 5 cropping seasons within 3 years. Results indicated that mean potato yield in dry seasons / irrigated (7.88t/ha) was higher than that of rainy (rainfed) cropping seasons (7.11t/ha) due to higher level of disease attack (bacterial wilt and soft rot), soil moisture content, mini erosion and weed competition in the rain fed croppings. Analysis of variance showed significant differences in germination, some apparent growth parameters, disease attack and yield (at $P<0.01$). Regression / correlation analyses indicated that collar girth had the highest positive correlation with yield ($r = 0.954$, $R^2 = 0.910$, $P < 0.01$) in rain fed cropping seasons while leaf count recorded the highest positive correlation with yield during the irrigated cropping seasons ($r = 0.958$, $R^2 = 0.913$, $P < 0.01$).
Keywords: seasons, effects, alley cropping, potato, yield

1.0 INTRODUCTION

Potato is a herbaceous plant, botanically called *Solanum tuberosum L.,* belongs to the Solanaceae family (Kay, 1987), requires well – drained sandy loam or clay loam with a very reasonable level of nutrients and tolerates a relatively soft soil to pave way for easy stolon development. Production of potato requires adequate supply of water especially during the dry season and it responds to differences in temperatures which eventually affect its yield (Kay, 1987). Mills (2001) observed that potato needs frost free days of 90 – 120 days and tuberization takes place at lower temperatures. The optimal temperature for tuberization is 12.8^0C, at 21.1^0C tuberization process decreases and can stop at 29. 4^0 C in certain cultivars and that maximum yield could be achieved at temperatures between 15.6 and 18.3^0C (Kay, 1987).With regard to the economic importance of potato (often called Irish potato), Okonkwo *et. al*. (1995) reported that 80% of the potato produced in the country (Nigeria) are consumed by boiling or frying while other products include potato crisps (thin sliced and fried potato, often used as snacks), potato chips, potato starch, starch used in pharmaceutical industry) and potato flour.

The main objective of this study is to make comparative analysis on the yield of potato under two different seasons (rainy/rainfed and dry/irrigated cropping seasons).This was achieved by assessing the germination/seedling emergence rates and percentages, apparent growth parameters (plant height, collar girth, leaf count and stem count), yield indices (tuber count and tuber yield) and level of disease attack during the two seasons under alley cropping.

2.0 MATERIALS AND METHODS

This study was conducted in the teaching and research farm of the Department of Agric. Extension and Management, Federal College of Forestry, Jos Plateau, Nigeria (between Latitude 8^0 50^1 N and $10^0 10^1$N, longitude 8^0 22^1E and 9^0 30^1 E (Udo, 1978). The average elevation is above 1250m above sea level, the climate is characterized by rainy (mostly April – Sept.) and dry (mostly Oct. – March) seasons, lowest minimum temperatures occur in December and January (14.74 and 14.24^0C) respectively, lowest maximum temperatures are in July, August and September which are respectively 26.5, 26.8 and 27.9^0C, while the highest mean maximum temperature (33.3^0C) is in April (Udo, 1978).

The experimental design employed was randomized complete block design (RCBD) consisting of 5 treatments and 3 replicates. It was an agroforestry (alley cropping) experiment, a table of random numbers was used in assigning treatments to each block. This RCBD is a two – way classification method comprising the blocks and treatments in columns and rows respectively. The mini- plots within each block were assumed to be homogenous while those outside each block were considered to be heterogenous due to possible / likely difference in soil fertility in the site.

The treatments applied during the rainy and dry seasons were the same and they are :

T_0: Potato planted on flat bed without tree rows and green manure of *Albizia lebbeck* (control).

T_1: Potato planted in the alleys (spaces) between *A. lebbeck* tree rows without green manure

T_2: Potato planted without tree rows of *A. lebbeck* tree row but with green manure at 5 ton ha^{-1}

T_3: Potato planted in the alley of *A. lebbeck* tree rows with its foliage as leaf mulch at 5 ton ha^{-1} not incorporated into the soil.

T_4: Potato planted in the alleys of *A. lebbeck* tree rows with its green manure incorporated into the soil at land preparation at 10 ton $ha\text{-}^{1}$.

The green manure and foliage (as mulch) were applied two weeks before planting (single application) and each plot size was 3m x 2m. The potato tubers were pre- sprouted prior to planting so as to pave way for uniform emergence (germination). There were three rows of potato plants within a plot (65cm between rows and 25cm within rows) the planting depth was 8- 10cm to prevent exposures of the tubers to sun's heat, rodents and bird damages (*Okonkwo et al.*, (1995). *A. lebbeck* tree rows were 0.60m and 2.0m within and between rows respectively and the *A. lebbeck* trees were at both sides of the plots with *A. lebbeck* trees (with $6.0m^2$ space as alley where potato tubers were planted.

Throughout the 5 cropping seasons (3 rainy and 2 dry seasons), tending operations were adequately carried out. These include watering (during dry seasons only), weeding, pest control (especially rodents), fire tracing (during dry seasons), erosion control (during rainy season) and shade (of *A. lebbeck*) reduction at the 3rd, 4th and 5th cropping seasons. The apparent growth parameters assessed were plant height, number of leaves (leaf count), number of stem (stem count) per stand and collar girth while the yield parameters include tuber count and tuber yield (weight in ton ha^{-1}). Also, prior to the measurement of the growth and yield indices, the potato seedlings' emergence rates and percentage were evaluated.

The frequency of irrigation was every 2 days, soil moisture was maintained at field capacity during tuber initiation, tuberization and bulking but reduced to 50% at maturation Irrigation (during season cropping) continued till 7 days to harvest and about 500 – 600mm was applied (King *et.al.*, 2003).

3.0 RESULTS AND DISCUSSION

In all the cropping seasons seedling emergence from the pre – sprouted potato tubers commenced on the 7th day after planting (7DAP) in all the treatments at different % levels. The highest percentage seedlings' emergence (PSE) was observed in T_0 (control) at 1st cropping season (CS1) which was in the rainy season with a mean value of 70%. The least value was recorded in T_2 in CS2 (irrigated/dry season) with a mean value of 24.0% at 7 DAP (Table1). Analysis of variance (ANOVA) indicated significant differences at 1% probability level among the treatments in both rainfed and irrigated cropping seasons (CS). The PSE was lower in the CS2 and CS4 (irrigated) when compared to CS1, CS3 and CS5 (rainfed). At 14 DAP, the PSE was significantly influenced by the treatments during the CS2 and CS4 (at $P = 0.01$) only while no treatment effect was observed at the 1st, 3rd and 5th cropping seasons (CS1, CS3 and CS5). However, no block effect was recorded in all the cropping seasons probably due to lack of reasonable fertility gradient (i.e. no significant difference in soil nutrient status among the blocks.

The significant effects observed in PSE was not unconnected with the fact that the emergence of the potato tubers after planting was in trickles and not all the potato tubers' seedlings emerged at once. This phenomenon agreed with Nwoboshi (1982) and Kareem *et. al.* (2002) that germination / seedlings' emergence occurs in trickles and not at once. The lower PSE in CS2 and CS4 (irrigated) was possibly as a result of higher rate of evaporation of moisture from the soil during the dry season and high bulk density. Olowolafe (2003) had earlier observed that the bulk density of soils derived from granites could be as high as 2.0 gcm^{-3} and such high density result in high degree of compaction which could delay or hinder seedlings' emergence. Also, De heus (1973) and Vapraskas (1988) reported that loam and clay with bulk densities that are above 1.46 - 1.63 gcm^{-3} result in hindrance to root penetration and inadequate aeration owing to compaction. Seasonal effect was significant at 1% probability level at 14 DAP (Appendix 1).

Table 1: Germination/Seedling Emergence, Growth and yield parameters of Irish potato in the 1st, 2nd, 3rd, 4th and 5th cropping seasons.

Treatments	Germination		Growth Parameters				Yield Parameters	
(5)	%S.E. (7 DAP)	%S.E (14 DAP)	Plant Ht (cm)	Leaf Count	Stem Count	Collar Girth(cm)	Tuber Count	Tuber Yield (t/ha)
1st Season								
T_0	70.0a	97.0a	44.7d	24.7d	3.0a	2.2e	112.3c	5.03d
T_1	52.06b	98.0a	51.3c	27.0d	2.7ab	2.8d	109.0c	5.08d
T_2	41.0c	97.0a	53.7c	41.3b	2.3ab	3.07c	139.0b	8.36b
T_3	62.0ab	97.7a	55.7b	35.7c	2.3ab	3.4b	113.0c	7.98c
T_4	57.3b	99.0a	66.3a	56.7a	2.0b	4.5a	160.7a	9.36a
2nd Season								
T_0	29.7b	92.7ab	48.0e	30.0c	2.3b	2.3e	79.7d	5.19e
T_1	24.3c	90.0ab	55.7d	35.0c	2.7a	3.0d	111.0c	5.43d
T_2	24.0c	87.0b	58.7c	53.0b	3.0a	3.4c	153.7a	9.72b
T_3	33.7a	87.7b	62.3b	52.0b	2.3b	3.5b	127.7b	8.90c
T_4	24.7c	95.0a	68.3a	67.3a	3.0a	4.7a	160.7a	10.41a
3rd Season								
T_0	58.3b	94.7b	62.0c	36.7d	3.0a	2.4e	92.3c	5.30e
T_1	54.7b	98.3a	65.0bc	52.3c	3.0a	3.3d	94.7c	5.40d
T_2	43.7c	98.0a	67.7b	61.7b	3.0a	3.6c	151.7a	9.13b
T_3	71.7a	97.7ab	63.7c	64.0b	2.7a	3.5b	118.0b	8.61c
T_4	56.7b	97.0ab	75.3a	70.3a	2.7a	4.9a	93.7c	9.80a
4th Season								
T_0	36.3b	93.0ab	64.7d	44.0e	3.0a	2.5e	95.7bc	5.22d
T_1	31.0c	92.0b	70.3c	60.0d	3.0a	3.5d	93.7c	5.74c
T_2	29.0c	95.0ab	76.3b	66.0c	2.0b	4.3b	142.7a	9.61a
T_3	33.0bc	84.0c	74.3b	72.3b	2.3b	4.1c	103.3b	8.90b
T_4	41.0a	97.0a	80.7a	77.7a	2.3b	5.3a	87.0d	9.73a
5th Season								
T_0	61.0a	93.0a	63.7d	46.0c	2.7a	3.1e	97.0c	5.28e
T_1	55.3a	91.7a	70.7c	72.3b	2.7a	3.5d	91.0c	5.85d
T_2	59.0a	92.3a	77.3b	71.0b	2.3a	4.4b	160.7a	9.63b
T_3	59.3a	94.0a	71.3c	70.3b	2.7a	4.2c	142.7b	9.02c
T_4	63.0a	94.0a	82.3a	78.7a	2.3b	5.3a	161.7a	11.96a

S.E. = Seedlings' Emergence. Mean values with the same letters are not significantly different at 5% level by Duncan's Multiple Range Test (DMRT). See Table 2 for what To-T_4 denote.

Plant height in the CS1, CS3 and CS5 (rainfed), T4 had the highest mean values of 66.3cm, 75.3cm and 82.3cm respectively while CS2 and CS4 (irrigated) respectively had 68.3cm and 80.7cm. It was CS4 (irrigated) that had the highest mean value (73.27cm) out of the 5 cropping seasons (CS) followed CS5, CS3 (rainfed), CS2 (irrigated) and CS1 (rainfed) with mean values of 73.07, 66.73, 58.60cm and 55.33cm respectively (Table1). Pertaining to effect of season and treatment x season on plant height, ANOVA showed significant effect at 1% and 5% probability levels respectively (Appendix 2). Duncan's Multiple Range Test (DMRT) indicated that the mean values of CS4 and CS5 were not significantly different but those of CS1, CS2, CS3 and either CS4 or CS5 (and not both) were significantly different.

On number of leaves (leaf count), significant effect was also recorded on the influence of seasons and treatment x season regarding the leaf count at 1% probability level (P = 0.01). It was CS5 rainfed) that had the highest mean value (67.67) followed by CS4 (irrigated), CS3, CS2 and CS1 with mean values of 64.00, 57.00, 58.60 and 37.09 respectively. With regard to stem count (i.e. number of stems), the 1st cropping season (CS1) had the lowest mean (average) stem count of 2.46 per replicate. CS3 had the highest mean stem count (2.88) out of the 5 cropping seasons. Generally, the stem count was not influenced significantly by the two seasons (Table 1, Appendix 2). Thus, there was no significant difference among the mean values of stem count from the five (5) cropping seasons. Owing to the fact that the difference between the highest (2.88) and the lowest (2.46) is 0.42 which was not enough to make a significant effect.

Seasonal effect on the collar girth from the 5 cropping seasons (CS) was significant (at 1% level: P = 0.01), Appendix 3) It indicated that CS1, CS3 and CS5 (rainfed) respectively had values of 3.19cm, 3.54cm and 3.97cm (grand mean = 3.57cm) while those of CS2 and CS4 (irrigated) got mean values of 3.59cm and 3.94cm respectively (grand mean = 3.69cm). The increase in the collar girth from one CS to the other was probably due to improvement in the nutrient status from CS1 – 5 (in those treatments with green manure application and *Albizia lebbeck* trees). The mean collar girth of the three rainy seasons was 3.57cm while those of dry seasons was 3.67cm though the value from the 5th rainfed cropping season (3.97cm) was the highest among the cropping seasons.

Seasonal effect on tuber count indicated that the highest value was obtained in the 2nd cropping season (irrigated) and this was followed by the 5th cropping season (rainfed) while the least value was observed in the 4th cropping season (irrigated). Significant differences were observed at $P<0.01$ on seasonal effect while that of treatment x season was at $P< 0.05$. Duncan's Multiple Range Test (DMRT) showed that the mean values of CS1 and CS3 differed significantly while those of CS1, CS2 and CS5 did not. Also, there were no significant differences (from analysis of variance) among the mean values of the treatments from CS3 and CS4.

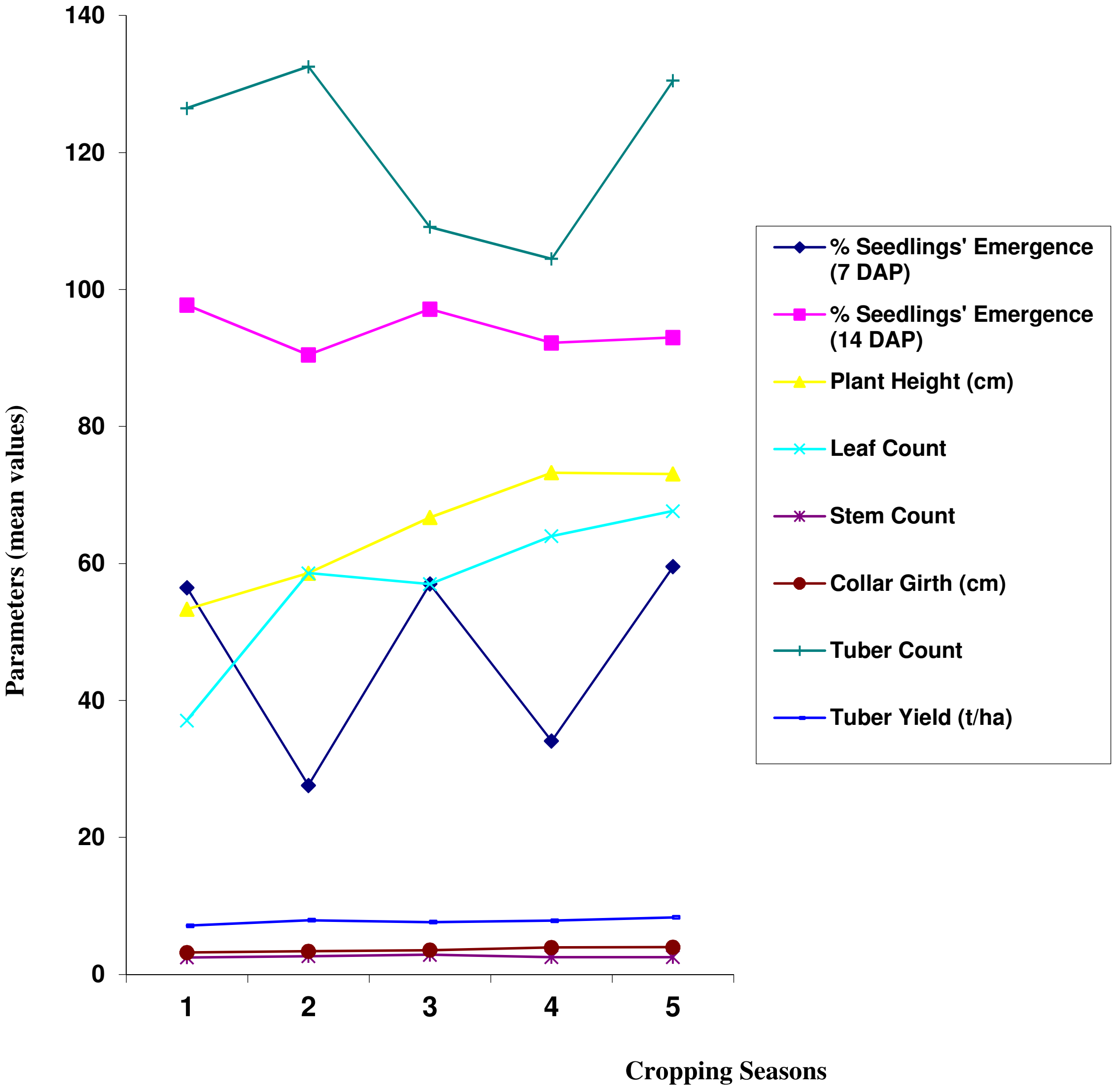

Fig. 1: Seasonal Effects on Growth and Yield Parameters of Irish Potato

Effect of seasons on the tuber yield was highly significant (P=0.0001), it showed that CS5 had the highest mean value of 8.34 t/ha while the values for the remaining 4 cropping seasons CS1, CS2, CS3 and CS4 were 7.16, 7.92, 7.63 and 7.84 t /ha respectively. DMRT indicated that the mean value of each of the 5 cropping seasons differed significantly (Appendix 4), the rainfed croppings (CS1, CS3 and CS5) had mean value of 7.11 ton ha^{-1} while the dry season (irrigated) cropping CS2 and CS4 had 7.88 ton ha-^{1} as mean value. The potato tubers harvested were of different sizes (Plate 1 below) ranging from < 30mm to > 50mm in diameter and the part of few tubers that were unknowingly exposed (not covered with soil) turned green (Plate 1d below), thus farmers should identify those exposed tubers and cover them with soil.

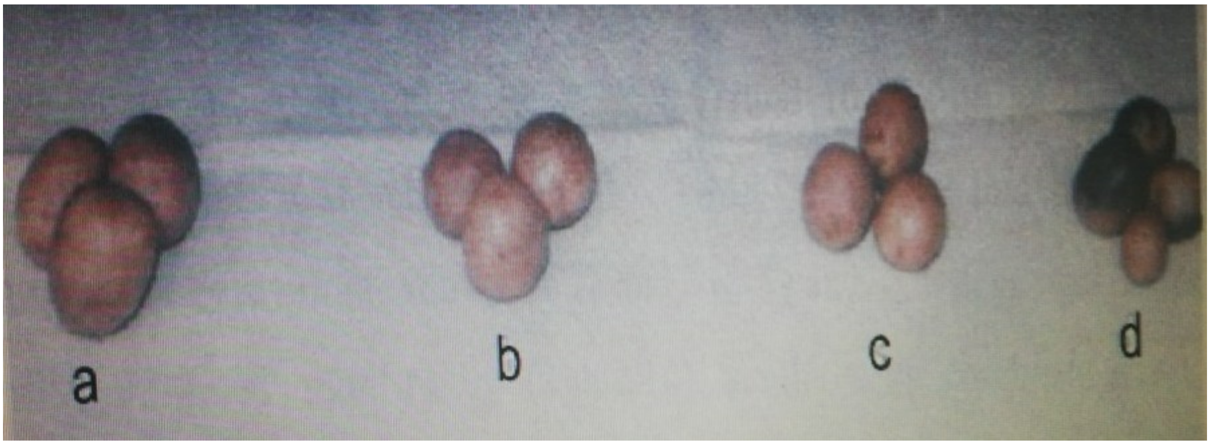

Plate 1: Different sizes of harvested potato tubers (a: > 50mm, b: 40-50mm, c: 30-40mm, d: < 30mm in diameter)

On the incidence of bacterial wilt (caused by *Ralstonia solanacearum*) and bacterial soft rot (caused by *Erwinia carotovora*), it was observed that these diseases were more prevalent during the rainy season cropping (Table 2, Figure 2) as opposed to the dry season cropping. Significant effect (at $P< 0.0001$), that is, CS1, CS3 and CS5 were more affected than CS2 and CS4 (Appendix 5). Potato harvest was done before the peak of the rainy season. The disease attack could have probably been more severe if potato crops were still on the field at the peak of the rainy season.

It could be deduced that the significant differences observed among some growth and yield parameters (plant height, collar girth and leaf count) in the five treatments could be attributed to differences in rates and methods of rattle tree *(Albizia lebbeck)* green manure application and presence or absence of *Albizia lebbeck* tree rows . When green manure was applied by mulching the decomposition rate was lower than when the green manure was incorporated into the soil (i.e. the green leaves were covered with soil). This also determines the rate at which nutrients are subsequently released to the soil.

Obviously, the treatment with tree rows of *A. lebbeck* (only T_1) had higher values of the growth parameters (probably due to higher nutrient status) than T0 (without green manure and trees of *A. lebbeck*) as a result of addition of nitrates to the growth medium through nitrogen fixation of the *A. lebbeck* and litter deposition (as from the 3rd to the 5th cropping season. Similarly, the treatment (T4) with highest rate of green manure application in addition to the presence of tree rows of *A. lebbeck* (Plate 2) had highest soil fertility level and subsequently recorded the highest values in growth parameters, owing the roles of the green manure and nitrogen fixation activities of the *A lebbeck* trees (Dhakel *et. al*., 2011).

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Pertaining to the seasonal effects (from one season to the other), factors such as varying moisture content levels in the agro forestry farm, increasing nutrient status due to manuring and nitrogen fixation activities of *A. lebbeck* trees, erosion effect, level of disease attack and weed competition were identified as causative factors. Firstly, the moisture or water transferred/translocated from the soil through plant roots and stems to the leaves (transpiration) and the water that disappeared inform of vapour from the soil surface in the experimental site (which is termed evapotranspiration) had a higher rate during the dry seasons as opposed to the rain fed cropping seasons.

Plate 2: ***A. lebbeck*** **tree rows and alleys where potato had been harvested (after the 5th season)**

Table 2: Incidence of disease attack (bacterial wilt /brown rot and soft rot) on the potato crop plants in the five cropping seasons.

Treatments			Cropping Seasons		
(s)	1	2*	3	4*	5
T_0	1	0	3	0	3
	2	0	3	0	2
	3	0	3	0	3
$\bar{x}$	2.0	0.0	3.0	0.0	2.7
S.D	0.82	0.00	0.00	0.00	0.66
T_1	1	0	1	0	1
	1	0	1	0	0
	1	0	1	0	0
$\bar{x}$	1.0	0.0	1.0	0.0	0.3
S.D	0.00	0.0	0.00	0.00	0.66
T_2	1	1	2	2	3
	1	2	2	2	3
	1	0	2	2	1
$\bar{x}$	1.0	1.0	2.0	2.0	2.3
S.D	0.00	0.58	0.00	0.00	0.18
T_3	3	2	1	2	2
	3	3	2	1	0
	3	1	3	0	1
$\bar{x}$	3.0	2.0	2.0	1.0	1.0
S.D	0.00	0.82	0.82	0.58	0.58
T_4	1	0	2	0	3
	2	0	3	1	3
	0	0	1	2	3
$\bar{x}$	1.0	0.0	2.0	1.0	3.0
S.D	0.58	0.00	0.82	0.58	0.00

$\bar{x}$ = Mean, SD = Standard Deviation, * Dry Season Croppings.

To = Plot without green manure and trees rows of *A. lebbeck* (Control)
T1 = Plot without green manure and but with tree rows of *A. lebbeck*
T2 = Plot with green manure at 5 ton/ha without tree rows of *A. lebbeck*
T3 = Plot with green manure (as mulch) at 5 ton/ha and tree rows of *A. lebbeck*
T4 = Plot with green manure at 10 ton/ha and tree rows of *A. lebbeck*

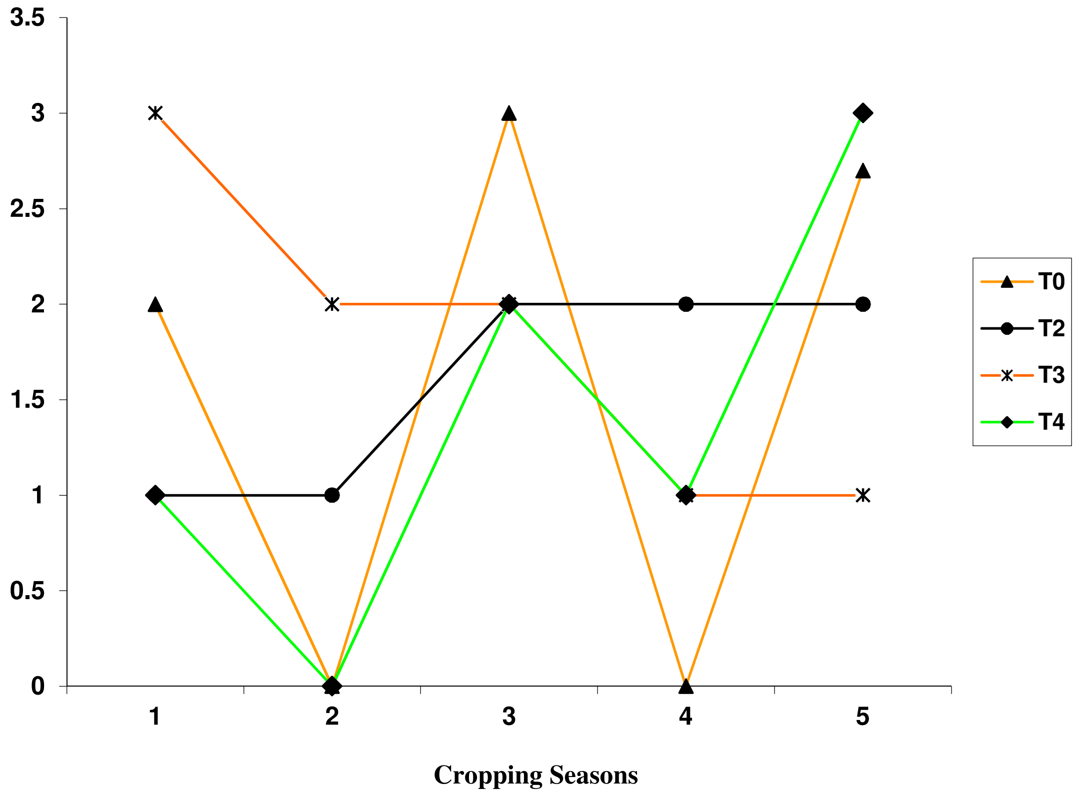

Fig. 2: Incidence of Disease Attack Bacterial Wilt and Soft Rot on Irish Potato Production from 5 Treatments and 5 Cropping Seasons (Mean Values)

Also, it was not easy to maintain soil moisture at field capacity during rainy season where as the frequency of irrigation (during dry season cropping) was every 2 days which paved for the maintenance of the soil at field capacity especially during tuber initiation / formation (tuberization) and bulking. The volume of water applied was reduced to 50% at maturation (of potato tubers) and irrigation was discontinued 7 days to harvest in order to ensure optimal harvest/yield (King *et. al*., 2003; Pawer and Dingre, 2014). Thus, these phenomena resulted in higher mean yield in the irrigated cropping season (CS2 and CS4) over the rainy seasons croppings (CS1, CS3 and CS5).

Increasing nutrient status in the agroforestry (alley cropping farm / agrisilvicultural farm) from one season to the other in those treatments with *A. lebbeck* green manure application and its tree rows could have also brought about the recorded differences / variations in the yield. For instance apart from T_0 (control), other treatments (T_1 – T_4) had either green manure of *A. lebbeck* or its tree rows, thus the fertility build – up from season to season sequel to the nutrient from the green manure and nitrates from the nitrogen fixation activities of the *A. lebbeck* tree resulted in different mean yields. Suresh and Rao (2000) and Dhakel *et. al.* (2011) had observed a reasonable increase in crop yield due to organic manuring (mulching) in potato and nitrogen fixation activities of some tree legumes including *A. lebbeck.* Adepetu *et. al.* (1979) had also earlier reported on the importance of organic matter on crop yield. In addition to the green manuring and mulching, organic matter was obtained from the leaves of *A. lebbeck* especially during the dry season due to the deciduous nature of this tree. Based on the result obtained, the higher mean yield from irrigated cropping seasons could have been as result of the increasing nutrient build – up in the alley cropping farm.

In another sphere, the influence of erosion could have also contributed to the difference in yields from the rainfed and irrigated croppings. During the rainfed cropping, there was erosion in some parts of the experimental site which must have possibly led to loss of nutrients where as the quantity of water applied during irrigation (in dry season cropping) was carefully calculated which did not pave way for erosion. The cropping seasons (CS) 1, 3, and 5 were rainfed while CS2 and 4 were irrigated but the mean yield from the irrigated CS (7.88 ton / ha) was higher than that of the rainfed CS (7.11 ton / ha). Thus, erosion and the soil moisture in the rainy that was above field capacity could have contributed to the variation in yield (Martha *et. al*., 2007; Pawar and Dingre, 2014).

Level of disease attack on the potato stands during the rainfed and irrigated CS is another contributory factor. It was observed that the incidence of brown rot or bacterial wilt (*Ralstonia solanacearum* L) and bacterial soft rot (*Erwinia carotovora*) was higher in rainfed CS than the irrigated CS. This is because more potato stands were affected by bacteria wilt and soft rot in the rainy (CS 1, 3, and 5) as opposed to CS2 and CS4 which were irrigated. In the rainy season, potato yield is often negatively affected by these disease (bacterial wilt/ brown and soft rot) and other diseases such as early blight and dark rot thereby lowering its yield (Okonkwo *et. al*., 1995, Kay, 1987; Oni, *et. al*., 2000; Muriithilinus and Irungu, 2004). In the dry season bacterial wilt/ brown rot and early late blight are reduced to the minimal level as opposed to the rainy season (Table 2, Figure 2 and Appendix 5). Analysis of variance (ANOVA) indicated significant difference at 1% probability level.

The rate of weed growth in the dry season was lower than that of the rainy season. This brought about higher rate or frequency of weeding in the rainfed cropping seasons. Though, experimental plots were not allowed to grow weedy prior to weeding but higher rate of weeds' emergence in the rainy was an indication of nutrient uptake by the weeds since weeds cannot grow without nutrient absorption from the soil. When nutrients are absorbed by weeds it decreases the amount of nutrient that would be available to crops. This influence of weed competition could have partially contributed to the lower mean yield in the rainfed cropping seasons (Gupta, 2006; Huxley *et al.*, 2009; Bolandi, *et al*., 2013, Samar *et al*., 2008).

Pertaining to the correlation between the apparent growth parameters (plant height, number of leaves, collar girth and stem count) and yield, it was observed that collar girth had highest significant effect (at 1%) on the potato yield in the rainfed cropping seasons than in the irrigated cropping seasons. But number of leaves had the highest significant influence (at 1% level) on yield during the dry season (irrigated) cropping while other growth parameters were only significant at 5% level except number of stem (stem count). Stem count recorded a negative correlation with yield (0.313% probability level, Table 1, Appendix 2). The higher value of R^2 (Coefficient of determination 0.913), r (correlation coefficient 0.956) and level of significance ($P<0.011$) of leaf count in the irrigated cropping season was probably as a result of the effect of number of leaves on tuber formation and tuber yield. Large leaf area index which is a function of leaf count resulted to higher level of photosynthetic activities and assimilation / accumulation of photosynthates for tuberization. Without reasonable duration of sunshine hours (all other factors being present in right proportions reasonable amount of photosynthates may not be accumulated. The sunshine hours during the irrigated cropping seasons were more than that of the rainfed cropping seasons. Thus, leaves play a vital role in crop growth, development and yield (Amadi *et al*., 2005).

4.0 CONCLUSION

Potato production during the dry season has many advantages over wet/rainy season cultivation. This was due to some seasonal effects which were observed at different levels of proportions during the study that subsequently resulted in variations in the growth, development and yield. Factors such as soil moisture content level (which was not easy to maintain at 60-70% field capacity during the wet season cropping), disease attack (bacterial wilt/brown rot and soft rot) and weed growth,/emergence rate which were higher in rainy season croppings and longer photoperiod (in dry season) brought about the higher mean yield recorded during the dry season croppings.

However, owing to the financial implication of providing the necessary manpower/financial resources for irrigation, early planting of healthy pre-sprouted 'bertita' variety of potato should be planted when rain stabilizes in April/May (depending on rainfall pattern) so as to avoid serious disease attack at the peak of rainy season. Also, productive/sustainable cultivation of potato can be achieved under alley cropping with *A. lebbeck* as indicated in all the cropping seasons by employing the treatment that had the highest rate of green manure application with the tree rows of *A.lebbeck* (T4) which recorded the highest yield in both rain fed and irrigated cropping seasons.

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Appendix 1: ANOVA Showing the Effect of Block, Treatment, Season and Treatment x Season on Leaf Count of Irish Potato at 63 DAP.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F Cal. Value	Probability Level
Block (Replicate)	2	4.67	2.33	0.66	0.5194 NS
Treatment	4	7600.00	1900.00	540.71	< 0.0001***
Season	4	8438.80	2109.70	600.39	< 0.0001***
Treatment x Season	16	1038.53	64.91	18.47	< 0.0100**
Error	48	168.67	3.51	-	-
Total	74	17250.67	-	-	-

*** = Highly Significant at 1%, ** = Significant at 1%, NS = Not Significant

Appendix 2: ANOVA Showing the Effect of Block, Treatment, Season and Treatment x Season on Stem Count Potato at 63 DAP

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F Cal. Value	Probability Level
Block (Replicate)	2	0.19	0.093	0.46	0.6362 NS
Treatment	4	1.92	0.480	2.35	0.0676 NS
Season	4	1.52	0.380	1.86	0.1331 NS
Treatment x Season	16	4.35	0.272	1.33	0.2194 NS
Error	48	9.81	0.204	-	-
Total	74	17.79	-	-	-

NS = Not Significant

Appendix 3: ANOVA Showing the Effect of Block Treatment, Season and Treatment x Season on Collar Girth of Irish Potato at 63 DAP

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.006	0.003	1.50	0.2340 NS
Treatment	4	51.282	12.821	6494.52	< 0.0001***
Season	4	7.064	1.766	894.62	< 0.0001***
Treatment x Season	16	1.77	0.111	56.12	< 0.0001***
Error	48	0.095	0.002	-	-
Total	74	60.219	-	-	-

*** = Highly Significant at 1%, NS = Not Significant

Appendix 4: ANOVA Showing the Effect of Block Treatment, Season and Treatment x Season on Tuber Yield of Irish Potato at 63 DAP.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.067	0.033	2.28	0.1137 NS
Treatment	4	315.716	78.929	5390.46	< 0.0001***
Season	4	11.235	2.809	191.82	< 0.0001***
Treatment x Season	16	9.36	0.585	39.96	< 0.0001***
Error	48	0.703	0.015	-	-
Total	74	337..081	-	-	-

*** = Significant at 1 %.

Appendix 5: ANOVA Showing the Effect of the Incidence of Bacterial Wilt/Brown Rot on Irish Potato Productivity at 63 DAP.

Source of Variation (S.V.)	Degree of Freedom (D.F)	Sum of Squares (S.S.)	Mean Square (M.S)	F cal. Value	Probability Level
Block (Replicate)	2	0.747	0.373	0.84	0.4366 NS
Treatment	4	16.747	4.187	9.46	< 0.0001***
Season	4	24.213	6.053	13.67	< 0.0001***
Treatment x Season	16	32.587	2.037	4.60	0.0500*
Error	48	21.253	0.443	-	-
Total	74	95.547	-	-	-

*** Highly Significant at 1 %, Significant at 5 %, NS = Not Significant.

Table 6: Multiple regression and correlation analyses: growth parameters versus yield of Irish potato (rainfed)

Variables	'a'	Std Error	Multiple R	R Square	F-Value	P Value
X_1	0.310	0.096	0.881	0.777	10.450	0.048*
X_2	0.173	0.047	0.905	0.820	13.653	0.034*
X_3	-5.982	1.761	-0.891	0.794	11.540	0.0426*
X_4	2.308	0.419	0.954	0.910	30.424	0.012**

* Significant at 5%, ** Significant at 1%

Table 7: Multiple regression and correlation analyses: growth parameters versus yield of Irish potato (irrigated)

Variables	'a'	Std Error	Multiple R	R Square	F-value	P.value
X_1	0.304	0.080	0.911	0.830	14.645	0.031*
X_2	0.150	0.027	0.956	0.913	31.631	0.011**
X_3	-6.314	5.214	0.573	0.328	1.467	0.313'
X_4	2.313	0.659	0.897	0.804	12.335	0.039*

* Significant at 5%, ** Significant at 1%, 'Not significant

Variable Description for Tables 7 and 8: X_1 denotes Plant Height , X_2 denotes Leaf Count (number of leaves), X_3 denotes Stem Count, X_4 denotes Collar girth, a = Incercept [the part the of the dependent variable (yield) that does not change or vary with change in the independent variables (plant height, leaf count, collar girth and stem count), R^2 = Coefficien of determination = proportion of variation in the dependent variable which is explained by the independent variable.