Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/13705
DOI URL: http://dx.doi.org/10.21474/IJAR01/13705

RESEARCH ARTICLE

Seedling emergence stability of Bambara groundnut [*Vigna subterranea* L. (Verdc.)] under savanna and humid rain forest areas conditions during two cropping seasons in Côte d'Ivoire

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Manuscript Info

Manuscript History
Received: 05 September 2021
Final Accepted: 10 October 2021
Published: November 2021

Key words:-
Bambara Groundnut, Seedling Emergence, Environment, Genotype, AMMI

Abstract

The yield of Bambara groundnut [*Vigna subterranea* L. (Verdc.)] is extremely low and unpredictable. Erratic yields have been attributed, at least in part, to variable or poor field establishment due to seedling emergence. The aim of this study wasto evaluate under field conditions, the effects of genotype and environment on seedling emergence in Bambara groundnut. Field experiment was conducted with 15 landraces in Northern and Southern regions of Côte d'Ivoire. A randomized complete block design with five replications was used in each environment. Estimated variables included number of day for emergence (DFE), mean emergence time (MET), emergence index (EI), time to 50% emergence (T50) and seedling emergence percentage (EP). Analysis of variance revealed significant ($P < 0.05$) differences between genotypes, locations and the interaction genotype x location for all traits studied. Location x year x genotype interactions were only significant for DFE, EI and EP.The highest DFE and T50 and MET were observed with the genotype Ci7. The least DFE, MET and T50 were obtained with genotypes Ci1, Ci2, Ci10, Ci11, Ci12, Ci13 and Ci22. Highest seedling emergence percentage was recorded with genotype Ci15 (93.29%) in Korhogo and Ci4 in Korhogo (90.85%) and Abidjan (89.59 %). Lowest EP was observed with the genotype Ci3 (42.33%).Correlations indicated that genotype with higher emergence percentage, emerged faster (low DFE, MET, T50) and exhibited higher emergence index (EI). AMMI analysis showed that Ci1, Ci4, Ci7, Ci11, Ci14 and Ci15 were the ideal genotypes because they expressed high and stable EP.

Introduction:-

Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is an important pulse crop cultivated by small-scale farmers over much of semi-arid, sub-Saharan Africa (Linnemann and Azam-Ali 1993). World production is about 330000 tones, 45 to 50 % of which are produced in West Africa (Brink and Belay 2006). A study by the International Trade Centre UNCTAD/GATT in the 1980s indicated that demand for the crop exceeded supply in West Africa (Coudert 1984). In term of production and consumption, it is the third most important grain legume in Africa after groundnut

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(*Arachis hypogea* L.) and cowpea [*Vigna unguiculata* (L). Walp] (Howell 1994). Bambara groundnut is mainly grown for its edible proteins (18 to 24 %), which contain high lysine and methionin, than most other grain legumes (Brough et al. 1993). Moreover, Bambara groundnut is useful in crop rotations, because it can improve the soil nitrogen status (Mukurumbira 1985). Despite its importance in terms of nutrition and improvement of soil fertility, it has been classified as an underutilized crop and is only receiving sustained research in the recent past (Massawe et al. 2005).

The physiological quality of seeds is determined by germination tests. Although this kind of test is widely used, their results do not normally predict the emergence potential and the behavior of seedlings in the field, where conditions are usually unfavorable (Barros et al. 2002). Seedling emergence in the field involves two biological processes: seed germination followed by radicle and shoot elongation. According to Maiti and Moreno-Limon (2001), high rate of seedling emergence and seedling establishment directly contribute to crop yield.

Germination of Bambara groundnut increase from 16.8 until 32.5°C, where it reaches a peak and declines until 39.5°C (Karikari et al., 1995). It usually takes seven to 15 days under favorable temperature (28.5 to 32.5°C) for Bambara groundnut to germinate; but under lower temperatures, it takes up to 31 days with some seeds remaining dormant indefinitely (Linnemann and Azam-Ali, 1993; Swanevelder, 1998). Early seedling emergence is an important agronomic trait for efficient crop management and production (Jefferson and Coulman, 2008; Thomas et al., 2009).

Germination or seedling emergence in Bambara is often erratic and variable (Sesay, 2009). This erratic yield has been attributed, at least in part, to variable or poor field establishment (Linnemann and Azam-Ali 1993). Locations and cropping season's effects on seedling emergence have been reported in sugar beet (Whittington 1973) and in groundnut (Wynne and Sullivan 1978). Cultivars differed in stability over environments for the percentage of emerged seedlings when the data were analyzed by regression. The differences between cultivars were greater in years or at locations when seedling emergence was poor because of adverse environmental conditions.

Numerous authors have reported experimental data on seedling emergence in Bambara groundnut (Makanda et al., 2009; Sesay, 2009). These studies showed that seedling emergence is related to seed intraspecific condition. However, there is scanty information about genotype, location and cropping season effects on seedling emergence potentiality and its impact on crop stability. Therefore, the present study aimed to evaluate under field conditions, the effects of genotype and environment on seedling emergence in Bambara groundnut.

Materials and Methods:-

Plant material

Plant material used in this study consisted of fifteen Bambara groundnut landraces with different seed coat colour, seed eye colour and seed size as shown in Table 1.

Table 1:- origins and seed description of the Bambara groundnut landraces studied.

Landraces	Seed description	origins
Ci1	Cream testa, no eye	Salamvogo (Ouangolodougou)
Ci2	Cream testa with red spots and grey butterfly-like eye	Zanapkokaha (Korhogo)
Ci3	Black and grey mottles on cream background with grey butterfly-like eye	Salamvogo (Ouangolodougou)
Ci4	Black testa, no eye	Korhogo
Ci5	Dark red testa, no eye	Kpatarakaha (korhogo)
Ci6	Cream testa with black butterfly-like eye	Poulo (Ferkessedougou)
Ci7	Purple testa with dark purple spots, no eye	Ouangolodougou
Ci10	Black rhomboid spots on cream background on both micropylar and non-micropylar ends with grey butterfly-like eye	Sediogo (Korhogo)
Ci11	cream testa with purple spots and black butterfly-like eye	Sediogo (korhogo)
Ci12	Red and grey mottles on cream background with grey butterfly-like eye	Sediogo (Korhogo)
Ci14	Red and grey mottles on cream background with grey	Korhogo

	butterfly-like eye	
Ci15	Light brownish red testa, no eye	Sediogo (Korhogo)
Ci20	Dark purple testa with black spots, no eye	Kawara (Ouangolodougou)
Ci21	Grey testa with butterfly-like eye	Kawara (Ouangolodougou)
Ci22	Light brown testa with red spots and grey butterfly-like eye	Waraniene (Korhogo)

Experimental sites

Field trials were conducted during the 2011 and 2012 cropping seasons in the northern savanna (Korhogo, 9°53' N, 6°49' W) and in the southern humid rain forest (Abidjan, 5°17'N, 4°22 W) of Côte d'Ivoire. In both years, plantings were made in June at Korhogo and in July at Abidjan. Korhogo is characterized by sandy and gravel soil and a semi-arid climate with an annual rainfall of about 1000 - 1300 mm and the mean monthly temperature was 30 °C. Abidjan is characterized by sandy soil, s with 1500 – 2000 mm and the mean monthly temperature was 27 °C.

Experimental design and management

In each site, the experiment was laid out in a randomized complete block design (RCBD) with five replications. Each plot was 6 m x 2.5 m size and consisted of seven rows with spacing of 30 cm between rows and a space of 50 cm between each genotype. The seeding rate was 70 seeds/plot with 14 seeds/row. Two seeds were sown at a depth of 3 – 5 cm per hole at 30 by 30 cm spacing which was later thinned down to one after emergence.

Seedling emergence was recorded four (4) days after sowing (DAS) and the established seedlings were counted until emergence stops. Seedlings were considered to have emerged when the first true leaf had broken from the soil and was visible. Parameters measured included number of day of emergence (DFE), mean emergence time (MET), emergence index (EI), time to 50 % emergence (T50) and seedling emergence percentage (EP).

EP was computed as number of emerged seedlings 15 DAS and expressed as a proportion of total number of seeds sown.

MET was calculated according to the equation of Moradi-Dezfuli et al. (2008).

$$MET = \frac{\Sigma D.n}{\Sigma n} \quad (1)$$

Where n is the number of seeds emerged on day D which is the number of days counted since the first emergence of seedling.

The T50 of seedlings was calculated according to Farooq et al. (2006) formula.

$$T50 = ti + \frac{[(N/2) - ni].[ti - tj]}{ni - nj} \quad (2)$$

Where N is the total number of emerged seedlings; ni and nj; cumulative number of seeds emerged by adjacent counts at times ti and tj when ni<N/2<nj.

The emergence index (EI) was calculated as described by the Association of Official Seed Analysts (1983).

$$EI = \frac{\text{No. of seedling emerged}}{\text{Days of first count}} + \cdots + \frac{\text{No. of seedling emerged}}{\text{Days of final count}} \quad (3)$$

Statistical Analyses

All experimental data were analyzed using analyses of variance (ANOVA) and Student-Newman-Keuls's multiple range test was used to compare means at 5 % level of probability. Before using ANOVA, percentages were transformed according to $\arcsin\sqrt{P}$ where P is the value in percentage. These tests were carried out with the software SAS 9.1.3 computer program (SAS institute 2002). Additive Main Effects and Multiplicative Interactions (AMMI) analysis was used to test Landraces stability (with respect seedling emergence percentage). This stability analysis was performed using CropStat software packages.

Results and Discussion:-

Analysis of variance and mean comparison

Analysis of variance (Table 2-3) revealed significant ($P < 0.05$) differences between location, genotype and the interaction location x genotype for all the traits studied. But, location x year x genotype interactions were significant only for number of days to first seedling emergence (DFE), emergence index (EI) and seedling emergence percentage (EP).The significant L x G effects demonstrated that genotypes responses were influenced by the location and then indicated the necessity of testing Bambara groundnut genotype at multiple locations. This observation is in line with the masking effects of variable environments reported by Goncalves et al. (2003).

Excepted DFE and EP, the factors explained which is the percentage of the sum of squares of one trait by total sum squares, showed that Bambara groundnut seedling emergence was most markedly affected by genotype (24 % - 46 %), followed by locations (14 % - 21 %) and finally their interaction (5 % - 20 %). Genotype x location x year interaction was significant for DFE ($P < 0.05$), EI ($P < 0.001$) and EP ($P < 0.001$) but their explained factor is lower compared to those of other traits. For all traits, the high explained factor was attributed to genotype effects. However, the main effect due to genotypes was significant for all traits ($P < 0.05$). This genotype variable sum squares indicated the presence of various genotypes.

Table 2:- Variance analysis of some studied traits in Bambara groundnut grown in two locations in 2011 and 2012.

		Traits									
		DFE		MET		EI		T50		EP	
Sources of variation	**DF**	**MS**	**Expl (%)**	**MS**	**Expl (%)**	**MS**	**Expl (%)**	**MS**	**Expl (%)**	**MS**	**Expl (%)**
Locations (L)	1	0.82^{*}	1.00	13.91^{***}	14.18	240.14^{***}	21.88	15.71^{***}	15.79	296.78^{**}	1.19
Crop - Year (Y)	1	1.03^{**}	1.25	0.03^{ns}	0.03	21.45^{***}	1.90	0.35^{ns}	0.35	146.72^{*}	0.59
Genotypes (G)	14	2.05^{***}	35.04	3.24^{***}	46.28	17.37^{***}	24.53	3.05^{***}	42.94	603.95^{**}	33.97
L x Y	1	0.34^{ns}	0.42	1.13^{ns}	1.160	2.08^{ns}	0.297	1.94^{***}	1.96	248.38^{**}	0.99
L x G	14	0.12^{*}	2.20	0.45^{***}	6.44	15.66^{***}	20.96	0.38^{***}	5.45	229.56^{**}	12.91
Y x G	14	0.66^{***}	11.27	0.13^{ns}	1.88	4.16^{***}	6.81	0.16^{ns}	2.30	198.16^{**}	11.14
Y x L x G	14	0.30^{*}	5.21	0.19^{ns}	2.77	7.33^{***}	10.18	0.14^{ns}	2.10	198.16^{**}	11.45
Error	210	0.14	-	0.108	-	0.574	-	0.119	-	203.58^{**}	-
Total	269	-	-	-	-	-	-	-	-	-	-

DFE- number of days to first seedling emergence; EI- emergence index; MET- mean emergence time; T50- time to 50 % emergence; EP- Emergence percent.

*, **, *** Significant at 0.05, 0.01 and 0.001 probability levels, respectively; DF- degrees of freedom, SS- sum of squares, MS- mean square, Expl-explained (sum of squares of one trait by total sum squares)

Mean comparison by Student-Newman-Keuls (SNK) multiple range test displayed significant difference between genotypes for all traits in the two localities (Korhogo and Abidjan) and during the two cropping seasons (2010 and 2011) (Table 3). DFE and T50 ranged from 5 to 6.33 DAS and 6.05 to 7.47 DAS respectively while mean emergence time (MET) fluctuated from 6.65 to 8.11 DAS. This finding confirms previous observations reported by Berchie et al. (2010) in Bambara groundnut. However, it's not in line with results reported by Goli et al. (1997), Karikari (2000) and Onwubiko et al. (2011). Indeed, according these authors, the T50 varied from 7 to 14 DAS, 14 to 24 DAS and 8 to 10 DAS respectively under their studies areas. Onwubiko et al. (2011) showed DFE was varied of 6 to 7 DAS. The highest DFE, T50 and mean emergence time (MET) were exhibited by genotype Ci7. The delay of emergence observed with several genotypes could be explained by the permeability of seed coat, the soil moisture and the origin or the seed size. The lowest DFE, MET and T50 were obtained with genotypes Ci1, Ci2, Ci10, Ci11, Ci12, Ci13 and Ci22. These seven genotypes had early emergence, emerging first at other genotypes. Therefore, these genotypes produced the highest emergence index; the lowest below 6 $days^{-1}$ was recorded for Ci3 in Abidjan and Korhogo. Numerous authors reported that the decrease of germination index is the result of a reduction in water potential and seed accessibility to water (Rdhan and Yanaht 1982). Probably, the decrease of emergence index with genotype Ci3 could be explained by the same phenomenon.

Table 3:- Means comparison of studied traits of Bambara groundnut grown in two environments.

	Traits			
Genotypess	**DFE (days)**	**MET (days)**	**EI (days^{-1})**	**T50 (days)**
Ci1	5.00 ± 0.00^{d}	6.92 ± 0.45^{de}	7.85 ± 1.92^{abc}	6.23 ± 0.49^{ef}
Ci2	5.11 ± 0.32^{d}	7.22 ± 0.39^{c}	7.65 ± 1.69^{abcd}	6.53 ± 0.36^{de}
Ci3	5.27 ± 0.46^{cd}	7.51 ± 0.49^{b}	5.31 ± 2.45^{i}	6.78 ± 0.54^{cd}
Ci4	5.55 ± 0.51^{bc}	7.55 ± O.54^{b}	8.21 ± 1.10^{a}	6.92 ± 0.56^{bc}
Ci5	5.72 ± 0.66^{b}	7.68 ± 0.47^{b}	6.19 ± 1.53^{h}	7.05 ± 0.53^{bc}
Ci6	5.61 ± 0.60^{bc}	7.92 ± 0.50^{a}	6.45 ± 1.37^{gh}	7.19 ± 0.53^{b}
Ci7	6.33 ± 0.48^{a}	8.11 ± 0.42^{a}	6.87 ± 1.05^{efgh}	7.47 ± 0.51^{a}
Ci10	5.11 ± 0.32^{d}	6.78 ± 0.58^{e}	7.44 ± 2.78^{bcdef}	6.05 ± 0.60^{f}
Ci11	5.00 ± 0.00^{d}	6.65 ± 0.21^{e}	6.37 ± 1.61^{gh}	6.07 ± 0.26^{f}
Ci12	5.16 ± 0.38^{d}	6.85 ± 0.50^{e}	7.25 ± 2.87^{cdef}	6.27 ± 0.50^{ef}
Ci14	5.11 ± 0.32^{d}	7.28 ± 0.35^{c}	8.13 ± 0.89^{ab}	6.51 ± 0.36^{de}
Ci15	5.38 ± 0.50^{bcd}	7.58 ± 0.46^{b}	7.56 ± 1.11^{abcde}	6.96 ± 0.51^{bc}
Ci20	5.55 ± 0.61^{bc}	7.57 ± 0.43^{b}	4.79 ± 1.10^{j}	6.84 ± 0.40^{e}
Ci21	5.11 ± 0.32^{d}	7.12 ± 0.40^{cd}	6.99 ± 1.50^{defg}	6.44 ± 0.37^{e}
Ci22	5.33 ± 0.48^{cd}	7.63 ± 0.34^{b}	6.76 ± 1.28^{fgh}	6.74 ± 0.24^{cd}
F	13.90	29.93	30.77	26.12
P	< 0.001	< 0.001	< 0.001	< 0.001
CV (%)	7.17	4.47	10.94	5.18

DFE- number of days to first seedling emergence; EI- emergence index; MET- mean germination time; T50- time to 50 % germination

Values within the same column followed by the same letters are not significantly different using Student-Newman-Keuls's multiple range test at 5 % probability level.

Table 4:- Seedling emergence percentage for 15 Bambara groundnut genotypes for two environments.

Genotypes	**Locations**		**Genotypes average**
	Abidjan	**Korhogo**	
Ci1	78.54^{defg}	82.11^{bcdefg}	80.32
Ci2	83.71^{bcdefg}	77.38^{efg}	80.54
Ci3	74.49^{fg}	42.33^{h}	58.41
Ci4	89.59^{abcd}	90.85^{ab}	90.22
Ci5	76.95^{fg}	77.15^{defg}	77.05
Ci6	73.63^{fg}	72.34^{g}	72.98
Ci7	79.00^{efg}	83.36^{bcdefg}	81.18
Ci10	89.44^{abcd}	72.94^{fg}	81.19
Ci11	84.88^{bcdef}	88.79^{abc}	86.83
Ci12	87.84^{abcde}	82.04^{bcdefg}	84.94
Ci14	84.11^{bcdefg}	82.41^{bcdefg}	83.26
Ci15	84.09^{bcdefg}	93.29^{a}	88.69
Ci20	78.61^{efg}	75.50^{fg}	77.05
Ci21	77.29^{efg}	73.80^{fg}	75.55
Ci22	80.48^{cdefg}	72.70^{g}	76.59
Location average	81.51	77.80	79.65

Values within the two columns (locations) followed by the same letters are not significantly different using Student-Newman-Keuls's multiple range test at 5 % probability level.

The percentage of emerged seedlings (EP) ranged in one hand between 73.63 and 89.59 % in Abidjan and in the other hand from 42.33 to 90.85 % in korhogo (Table 4). The highest seedling emergence percentage was recorded with genotype Ci15 (90.85 %) in Korhogo and with Ci4 in Abidjan (89.59 %). The lowest EP was observed with genotype Ci3 (42.33 %) in Korhogo. Ci3 consistently produced the fewest seedlings averaging only 58.41 % seedlings emerged while Ci1, Ci2, Ci4, Ci7, Ci10, Ci11, Ci12, Ci14 and Ci15 averaged over 80 % seedlings emerged for the two locations. The percentage of seedling that emerged in Abidjan (81.51 %) over the two years

period was higher comparatively to Korhogo (77.80 %). The lower emergence percentage in Korhogo may resulted from poor seed–soil contact. Indeed, the soil of korhogo is sandy-gravel type. Soil that is sandy gravel may not be good for seedling emergence: a loose seedbed out too quickly and gives poor contact between the seeds and the soil; seeds may not emerged and water retention capacity is reduced in this kind of soil. According to Hosseini et al. (2009), a low soil moisture reduced emergence percentage, delayed the first day for emergence and suppressed the early growth in chickpea (CicerarietinumL.). The variation observed in Bambara seedling emergence is similar to previous results reported by Sesay (2009). This author concluded that seedling emergence in Bambara groundnut is often erratic and variable.

Table 5:- Correlation coefficients among seedling emergence traits in 15 Bambara groundnut genotypes.

	DFE	MET	EI	T50	EP
DFE	1				
MET	0,852	1			
EI	-0,258	-0,268	1		
T50	0,895	0,982	-0,252	1	
EP	-0,047	-0,268	0,648	-0,187	1

DFE- number of days to first seedling emergence; EI- emergence index; MET- mean germination time; T50- time to 50 % germination; EP- seedling emergence percentage

Simple correlation coefficients calculated with seedling emergence component in Bambara groundnut are illustrated in Table 5. Number of day to first emergence (DFE) was highly correlated with mean emergence time($r = 0.85$) and time to 50 % emergence ($r = 0.89$) respectively. A significant relationships was found between emergence index and emergence percentage ($r = 0.64$). Furthermore, relationships between seedling emergence percentage, mean emergence time and time to 50 % emergence were not significant. The results also indicated that genotypes which emerged faster (low DFE, MET, T50) had high emergence percentage. In addition, the seedlings had good vigor. Seedling emergence speed could be explained by the emerging apex's morphology. According to Benjamin (1982), the epicotyl of genotypes which emerged faster exerts a higher pressure to emerge than other genotype.

Genotype x Environment effects

Given the diversity of genotypes, locations, and crop season of field experiments, location x year and location x year x genotype interactions (GEI) were significant. Because, GEI was significant (Table 3) for emergence percentage, as mentioned AMMI analysis was used to estimate the highest stable genotype. AMMI analysis of variance of emergence percentage of 15 genotypes across four environments (location and year) showed that 47.01 % of the total sum of squares (explaining of Genotype, environment and genotype x environment) was attributed to genotype effects, whereas environment and genotype x environment interaction (GEI) effects explained 3.84 % and 49.14 %, respectively (Table 6).

Table 6:- AMMI analysis of variance.

Sources of variation	**DF**	**S.S**	**M.S**	**Explained (%)**
Genotype (G)	14	1691.07	120.791^{***}	47.01
Environment (E)	3	138.380	46.1265^{**}	3.84
G x E	42	1767.67	42.0873^{***}	49.14
IPCA 1	16	1244.68	77.7925^{***}	70.41
IPCA 2	14	318.633	22.7595^{ns}	18.02
IPCA 3	12	204.355	17.0296^{ns}	11.56
Total	59	3597.12		

*, **, *** Significant at 0.05, 0.01 and 0.001 probability levels, respectively. LSD G (0.05) = 3.34; CV % = 8.35; SS- Sum of squares; MS- mean squares; Explained- sum of squares of one trait by total sum of squares)

Genotype, environment and GEI effects were significant ($P < 0.01$), indicating broad range of diversity existing among genotypes (Vijayakumar et al. 2001). Significance of the environments indicated distinctness of intrinsic factors in different environment (Anandan et al. 2009). Variation induced by genotype was larger than that due to GEI. But, a significant GEI meaning that differences among genotypes varied across environments (Admassuet al. 2008). This case, along with a highly significant GEI, required stability analysis test.

AMMI analysis revealed that the sum of squares due to G x E interaction was partitioned into Interaction Principal Component Axis 1 (IPCA 1), IPCA 2 and IPCA 3 (Table 6). Mean square for the IPCA was significant at $P < 0.001$. IPCA 1 captured 70.41 % of the interaction sum of squares in 38.10 % of the interaction degrees of freedom. Furthermore, IPCA 1 had sums of squares greater than that of genotypes. Therefore, IPCA 1 factor has a high contribution to the interaction sum of squares. This indicates that one fundamental factor affects GEI; this could be either genotypic or environmental in nature (Anandan and Eswaran 2006). The most accurate model for AMMI can be predicted by using the first two IPCAs (Zobel et al. 1988; Gauch and Zobel 1996; Yan and Rajcan 2002). Conversely, Sivapalanet al. (2000) have recornrnended a predictive AMMI model with the first four PCAs. These results indicate that the number of terms to be included in an AMMI model cannot be specified in a priori without trying AMMI predictive assessment.

For interpretation of the AMMI 1 biplot, the magnitude and signal of the scores of the IPCA 1 are observed; the greater the IPCA 1 scores, either negative or positive (as it is a relative value) the more specifically adapted is a genotype to an environment. The closer the IPCA scores to zero, the more stable or adapted the genotype is in all environments (Gauch and Zobel 1990; Egesi and Asiedu 2002; Tarakanovas and Ruzgas 2006). Stability regressions of Bambara groundnut seedling emergence for each cultivar by means of EP in each environment are illustrated in Table 7. Genotype displaying the less Slope, MS-TXL, MS-REG, MS-DEV compared to the others was the most stable. Table 7 and figure 1 analyzed simultaneously revealed that the genotypes Ci1, Ci4, Ci5, Ci6, Ci7, Ci11, Ci14, Ci15, Ci20, Ci21, Ci22 were adapted to all environments. These genotypes belonged to quadrant I and II. Among them, Ci14 was the most stable genotype. Genotypes Ci5, Ci6, Ci20 and Ci22 had more stable but lower EP (quadrant I). Genotypes Ci1, Ci4, Ci7, Ci11, Ci14 and Ci15 exhibited high and stable EP indicating their adaptability hence they can be deployed in the region or used for further improvement of stable genotypes. There were the ideal genotypes (quadrant II). In quadrant III, Ci2, Ci10 and Ci12 were unstable and expressed high EP. They may be characterized by specific adaptation in favorable environments. Genotypes Ci3 was unstable and low EP across all environments. It was determined to be poorly adapted to the environments studied.

Table 7:- Stability regressions of emergence percentage for each genotype on means of emergence percentage at each environment (Location x year).

Genotypes	Mean (%)	Slope	SE	MS-TXL	MS-REG	MS-DEV
Ci1	80.33	0.905	2.326	135.85	102.37	152.6
Ci2	80.55	2.057	0.647	18.38	31.51	11.82
Ci3	58.41	6.74	1.431	348.19	929.16	57.71
Ci4	90.22	0.251	0.206	15.5	44.1	1.2
Ci5	77.05	3.063	2.107	238.6	465.53	125.14
Ci6	72.99	0.827	0.603	7.11	0.84	10.24
Ci7	81.18	0.291	0.653	23.67	46.98	12.01
Ci10	81.19	5.095	0.554	163.37	472.83	8.65
Ci11	86.84	0.788	0.448	33.83	90.14	5.67
Ci12	84.94	2.421	1.024	38.71	56.94	29.59
Ci14	83.26	0.88	0.403	3.18	0.35	4.59
Ci15	88.69	1.788	0.506	77.86	219.12	7.22
Ci20	77.06	0.813	0.662	8.56	0.99	12.34
Ci21	75.55	1.609	1.47	44.11	10.45	60.94
Ci22	76.59	1.635	0.767	14.85	11.37	16.6

Slope: Slopes of regressions of cultivar means on environment index. *Slope significantly different from the slope for the overall regressions which is 1.00. MS-TXL: Contribution of each cultivar to interaction MS. MS-REG: Contribution of each cultivar to the regression component of the treatment by location interaction. MS-DEV: Deviations from regression component of interaction.

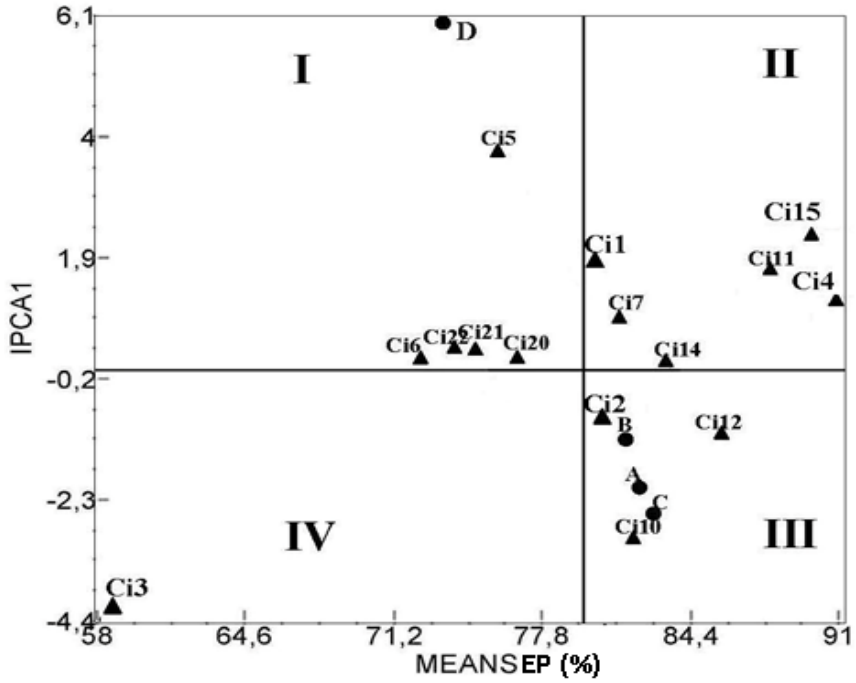

Figure 1:- AMMI 1 model biplotfor emergence percentage (EP %) of 15 Bambara groundnut genotypes in four environment. **A-** Abidjan 2011, **B**- Korhogo 2011, **C**- Abidjan 2012, **D**- Korhogo 2012.
I- Stable genotype and low EP, **II**- Stable genotype and high EP, **III**- Unstable genotype and high EP, **IV**- Unstable genotype and low EP.

Conclusion:-

Analysis of variance revealed significant ($P < 0.05$) differences for genotype, location and genotype-location for all the traits studied. The highest DFE, T50 and MET were observed with the genotype Ci7 in Abidjan and Korhogo. The lower DFE, MET and T50 were displayed by genotypes Ci1, Ci2, Ci10, Ci11, Ci12, Ci13 and Ci22 in Abidjan and Korhogo. These seven genotypes are early emerged. The correlation study indicated that genotype with high emergence percentage, emerged faster (low DFE, MET, T50) and they had a higher emergence index (GI). The analysis of variance by AMMI model of Bambara groundnut seedling emergence percentage (EP %) showed that genotype, location, year and their interaction and AMMI component 1 were significant. Genotypes Ci1, Ci4, Ci7, Ci11, Ci14 and Ci15 were the ideal genotypes because they showed high and stable EP. Genotype Ci3 was unstable and characterized by low EP.

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