

Full Length Research Paper

Assessment of sixteen varieties of groundnut in two agro ecological zones in Burkina Faso for yield and tolerance to aflatoxin

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In Burkina Faso, groundnut (*Arachis hypogaea* L.) is produced in almost the entire country except the north. Its multiple uses make it a highly appreciated oil seeds and leguminous crop. However, the presence of aflatoxins in grains constitutes a public health risk and thus limits its marketing to international markets. The present study evaluated sixteen (16) short duration (90 days) groundnut varieties (15 varieties received from ICRISAT Mali and one variety from INERA). The main goal was to evaluate the agronomic performance and the level of resistance of each variety to total aflatoxins in two locations (Gampela and Tenkodogo). The design was Blocks of Fisher completely randomized with three (3) replications and two factors were studied: The variety at sixteen (16) levels and the location at two (2) levels. The average pods yields were above 1 ton in the 2 locations. The best yields were observed from ICGV-IS 13806 (2394.97 kg.ha⁻¹) at Gampela and ICGV-IS 13912 (1804.78 kg.ha⁻¹) at Tenkodogo. In both locations, *Aspergillus flavus/parasiticus* contamination rates and the aflatoxin contamination amounts of the varieties were low (0 - 3.9 ppb). Aflatoxin contents varied depending on the degree of maturity of the seeds: Thus immature seeds (M3) had higher aflatoxin contents than mature seeds (M2 and M1). These low levels are the result of strict application of good agronomic practices and sorting. The negative correlation between the percentage of maturity of grains and the aflatoxins contents and the positive correlation between the percentage of maturity of grains and the shelling ratio indicate that an early sowing allowed good filling of pods and then the very significant reduction of aflatoxins contamination. The positive correlation also between the shelling ratio and the pods yields shows that when the pods are full they weigh more and increase the yield. However, the varieties to be adopted by producers must have good technological characteristics such as good shelling ratio and good weights of 100 seeds and less pods and seeds damaged. Varieties that would meet these criteria would be ICGV-IS 13824, ICGV-IS 13834 and ICGV-IS 13912.

Key words: Aflatoxins contaminations, groundnut, locations, varieties, yields.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.), a sub-American originated crop is one of the scarce underground fruiting

legumes produced all over the world. The genus *Arachis*, a member of the family of Fabaceae (ex-Leguminoseae),

is widely distributed in the tropics regions. It is an important source of edible oil for millions of people living in the semi tropic region. It is also a rustic, plastic and less water demanding plant (Youssi, 2008) mainly produced for human nutrition and is consumed in different forms: grain, oil, paste. The grains of groundnut are very rich in lipids (45-54%), proteins (20-36%) and carbohydrates (9-12%) (Youssi, 2008). They also serve as source of nutritive fiber, minerals and vitamins. The haulms are used for animals feed because rich in proteins. Often, the haulm constitutes the principal source of nutrients for small ruminants during the off season (FONCEKA, 2010).

In Burkina Faso, groundnut is cultivated almost over the whole country except the northern part which is very arid. According to the 'Direction Générale des Études et des Statistiques Sectorielles', DGESS/MARHASA (2015; 2016), there are enormous fluctuations on groundnut production area, groundnut production and yields. Since the 1990s, yields did not significantly change. It ranged between 600 and 900 kg.ha⁻¹, it was 714 kg.ha⁻¹ in 2000, 803 kg.ha⁻¹ in 2005, 830 kg.ha⁻¹ in 2010 and 832 kg.ha⁻¹ in 2015. The yields remain low compared to those of the biggest production countries. Therefore, it was necessary to screen high yielding varieties in order to register them in the regional varieties catalogue of the Economic Community of West African States (ECOWAS) and then make them available to the seed producers. Sixteen short cycle duration varieties were assessed at Gampela research station and in farmer's field at Tenkodogo. The general objective of this study was to evaluate the agronomic performance of 16 early maturing groundnut varieties. The specific objectives were to (i) assess seedling density and flowering time of each variety and (ii) assess yield and technologic quality of each variety.

MATERIALS AND METHODS

Study sites

The trials were conducted during the 2016 rainy season in two sites located in two agro-ecological zones: Gampela in Sudano-Sahelian climate with average rainfall between 700 and 900 mm (Zongo, 2015) and Tenkodogo in North Sudanian climate with average rainfall ranging between 750 and 1000 mm (MED, 2005). The later location belongs to the largest groundnut production zone in Burkina Faso.

Genetic material

The genetic material was composed of 16 varieties from ICRISAT/Mali and Burkina Faso. Some characteristics of these varieties are presented in Table 1.

Experimental

The experimental design was a 4x4 alpha lattice design with three replications in each of the two locations. In the replication, each plot contained 4 rows each lengthy to 4 m. Data were collected on the two central rows. The field was ploughed before experiment establishment. The soil was a sandy-clay type in the two locations. Two factors were studied:

- (1) The variety factor at sixteen (16) levels corresponding to the 16 varieties in Table 1.
- (2) The location factor at two (2) levels corresponding to the 2 locations where trials have been conducted (Gampela and Tenkodogo).

One seed, previously treated with Calthio C, were sowed per hill. Planting density of 60 cm between rows and 10 cm within rows was observed as recommended by International Crops Research Institute for Semi-Arid Tropics (ICRISAT). The trials were established after a rainfall of 66 mm at Gampela and 41 mm at Tenkodogo. Hand weeding and NPK fertilizer (14-23-14 at 100 kg.ha⁻¹) application were done at 15 days after planting (DAP). Ridging was done at 44 DAP. No phytosanitary treatment was applied and plants have been harvested on the 90th DAP because the varieties are short duration maturing (90 days). Plants on two central rows were uprooted and dried outside on the drying area of the Gampela research station for a week. Thereafter, pods were collected and weighed.

Rainfall data

Only rainfall data have been obtained from meteorological stations of IDR for Gampela and the Ministry of Agriculture for Tenkodogo, respectively because these small stations could not register air temperature and humidity that we needed. Total rainfall of 750 mm at Gampela and 665 mm at Tenkodogo has been recorded. Decades 1, 3 and 5 recorded the highest rainfalls (115, 155 and 111 mm) at Gampela whereas at Tenkodogo the highest rainfalls were recorded in decades 1, 2, and 6 (106, 108 and 101 mm) (Figure 1). It has been noted that it did rain during some periods at the end of the rainy season corresponding to crop maturing period.

Data collection

The following are the data collected:

- (1) Emergence rate: 10 days after planting (DAP). It was obtained as:

$$\text{Emergence rate} = \frac{\text{number of emerged plants}}{\text{total number of hills}} \times 100$$

- (2) Days to first flowering: Corresponding to the number of days from sowing to the appearance of the first flower on each plot. It was determined from daily observation each morning, starting from the 17th DAP.

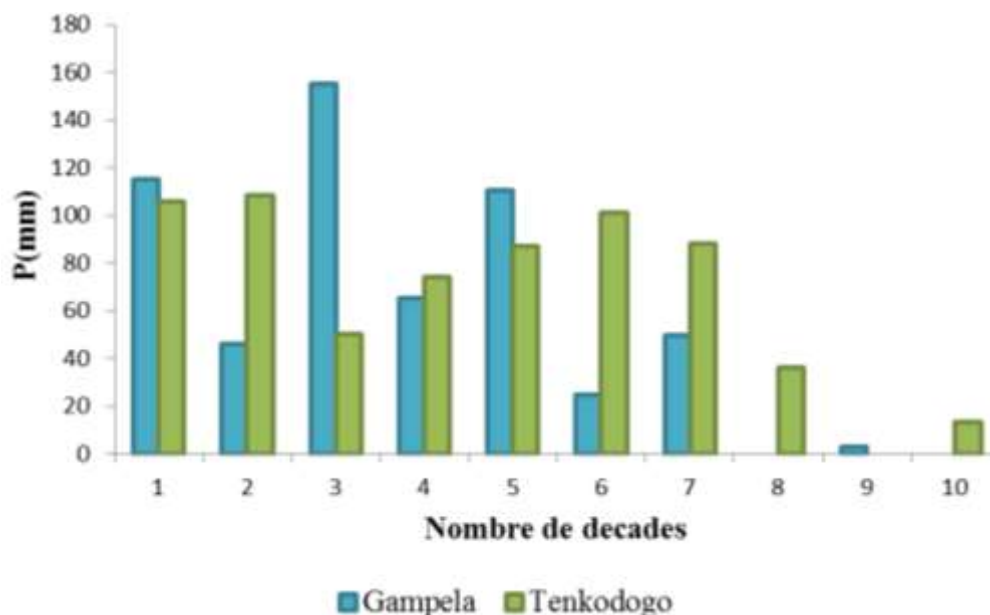
- (3) Days to fifty percent flowering: Represent the number of days

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Table 1. List of sixteen varieties and their characteristics.

No.	Variety	Origin	Botanic type	Cycle (days)	Characteristics
1	ICGV-IS 13806	ICRISAT	Spanish	90	Drought tolerant
2	ICGV-IS 13809	ICRISAT	Spanish	90	Drought tolerant
3	ICGV-IS 13912	ICRISAT	Spanish	90	"
4	ICGV-IS 13824	ICRISAT	Spanish	90	"
5	ICGV-IS 13825	ICRISAT	Spanish	90	"
6	ICGV-IS 13827	ICRISAT	Spanish	90	"
7	ICGV-IS 13830	ICRISAT	Spanish	90	Drought tolerant
8	ICGV-IS 13834	ICRISAT	Spanish	90	Drought tolerant
9	ICGV 86024	ICRISAT	Spanish	90	Foliar diseases tolerant
10	ICGV 86015	ICRISAT	Spanish	90	Foliar diseases tolerant
11	ICGV 93305	ICRISAT	Valencia	90	Aflatoxin tolerant
12	ICGV 93328	ICRISAT	Spanish	90	Aflatoxin tolerant
13	ICGV 91317	ICRISAT	Spanish	90	Aflatoxin tolerant
14	ICGV 91315	ICRISAT	Spanish	90	Aflatoxin tolerant
15	ICGV 94379	ICRISAT	Spanish	90	Aflatoxin tolerant
16	KIEMA	INERA	Spanish	90	Drought tolerant

**Figure 1.** Rainfall distribution per decade at Gampela and Tenkodogo in 2016.

from sowing to the day when 50% of plants in a plot flowered.

(4) Leaves spot severity: This was evaluated by scoring leaves damages on 5 plants chosen randomly in a plot according to Subrahmanyam et al. (1982) scale with 9 points. Generally, plants with a score from 1 to 3 are resistant, 4 to 6 are moderately resistant and 7 to 9 are sensitive.

(5) Yield and yield components: Dry haulm and pod weighs have been measured using a scale of precision (Mettler). Haulm yield and pods yields were expressed in kg per hectare as follows:

$$\text{Yield (kg.ha}^{-1}\text{)} = \frac{\text{weight per plot (kg)}}{\text{area of plot (m}^2\text{)}} \times 10\,000$$

(6) The technologic quality analysis of each variety: This was conducted on a sample of 200 g of dry pods taken from each variety to determine

(i) Shelling ratio of unsorted seeds: As determined based on dry pod sample of 200 g from each variety and each replication as

follows:

$$\text{Shelling ratio (\%)} = \frac{\text{seeds weight}}{200} \times 100$$

(ii) Good seeds ratio: Determined based on sorting the seeds of the dry pod sample of 200 g from each variety and each replication as follows:

$$\text{Good seeds ratio (\%)} = \frac{\text{sorted seeds weight}}{200} \times 100$$

Determination of the aflatoxins contents of the seeds of the three (3) classes of maturity of each variety

The groundnut samples were analyzed at INERA-Kamboise Phytopathology laboratory following the ELISA Agra Quant 1-20 ppb method from ROMERLABS. The samples were ground with a Blender and sieved. 20 g of powder was weighed and mixed with 100 ml of methanol at 70% (v/v) then filtered with Whatmann filters. 200 μ l of the «Conjugate» was introduced in the blue-green micro tubes to which were added 100 μ l of each sample and all were well mixed. 100 μ l of the mixture was transferred to the micro tubes containing the anti-aflatoxins antibodies. The mixtures were left to incubate at room temperature for 15 min. The micro tubes were washed 5 times with distilled purified water and 100 μ l of the «Substrate» were added to the micro tubes and incubated for 5 min at room temperature. Finally, 100 μ l of the «Stop Solution» were added and the samples contents were read by the Reader STAT FAX 303 PLUS with a calibration curve pre-established with 0, 1, 2, 4, 10 and 20 ppb standards.

Percentage of maturity of the varieties

Five (5) plants were randomly chosen at the harvest time and their pods were removed. These pods have been shelled and classified into three (3) classes of maturity on the basis of the colour of the shell parenchyma. If this parenchyma colour is dark, the pod is mature but if it is white the pod is immature

Data analysis

Graphs of means values were drawn with Excel 2013. Data were subjected to analysis of variance (ANOVA) and multivariate analysis in Spad v55 and Genstat Discovery Edition. Means separation was done using Students Newman-Keuls (SNK) test at 5% degree of confidence.

RESULTS

Emergence rate at 10 DAP for both sites

The results of the emergence rate at 10 DAP are presented in the Figure 2. The analysis of variance showed significant difference between the varieties for the emergence rate at 10 DAP for both sites (P-value = 0.001). At Gampela the mean emergence rate was 92.68%, ranging from 81.09 to 97.03%, whereas at Tenkodogo it varied between 67.58 and 94.83% with a mean of 88.35%. At Gampela, variety ICGV 93328 had

the best emergence rate (97.03%) while at Tenkodogo, variety ICGV-IS 13830 was the best (94.83%). In this locality, variety ICGV 93328 recorded the lowest emergence rate. With 88.62%, variety ICGV 93305 had the lowest rate at Gampela.

Days to first flowering

The mean days to first flowering was 21 DAP at Gampela and 22 DAP at Tenkodogo. At Tenkodogo the early flowering varieties were ICGV 91317, ICGV 94379 and KIEMA (20 DAP) followed by ICGV 93305 (21 DAP) and the first flowering dates ranged from 20 to 22 DAP. At Gampela, the first flower appeared between the 21st and 23rd DAP (Figure 3).

Days to 50% flowering

For both sites, the mean day to 50% flowering was 25 DAP. At Gampela, varieties ICGV 93305 and ICGV 94379 reached 50% flowering on the 23rd DAP likewise varieties ICGV 94379 and KIEMA at Tenkodogo (Figure 4).

Leaves spots severity

For leaves spots severity, Subrahmanyam et al. (1982) scale with 9 points used showed:

(1) At Gampela:

- i) At 60 DAP, the scores of the varieties were from 2 to 3 (ICGV-IS 13830)
- ii) At 75 DAP, the score of all the varieties was 4 (means from 3.67 to 4.33)
- iii) At 85 DAP, scores were between 5 (ICGV 93305, ICGV 94379) and 7 (ICGV 93328, ICGV-IS 13809, ICGV-IS 13825 and ICGV-IS 13827).

(2) At Tenkodogo

- i) At 60 DAP, the scores varied between 2 and 3. Nine varieties had score 2 and 7 varieties had score 3.
- ii) At 75 DAP, the scores varied from 3 to 4 with only ICGV 86015 and ICGV-IS 13830 which had score 3.
- iii) At 85 DAP, ICGV 93305 had score 5, ICGV-IS 13806 and ICGV-IS 13825 had score 7.

Regards to the results of diseases, scores comprised between 5 and 7 at 85 DAP in the two sites (Figures 5 and 6), the varieties should be moderately sensitive to leaves spots.

Pods and haulms yields (kg.ha⁻¹)

Results of the statistical analysis of pods yields showed significant differences for both Gampela and Tenkodogo

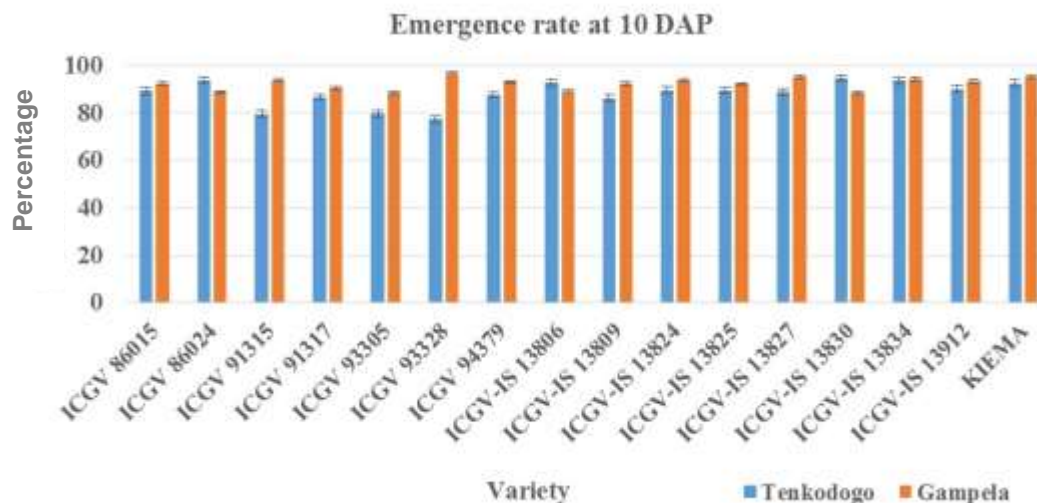


Figure 2. Emergence rate at 10 DAP at Tenkodogo and Gampela.

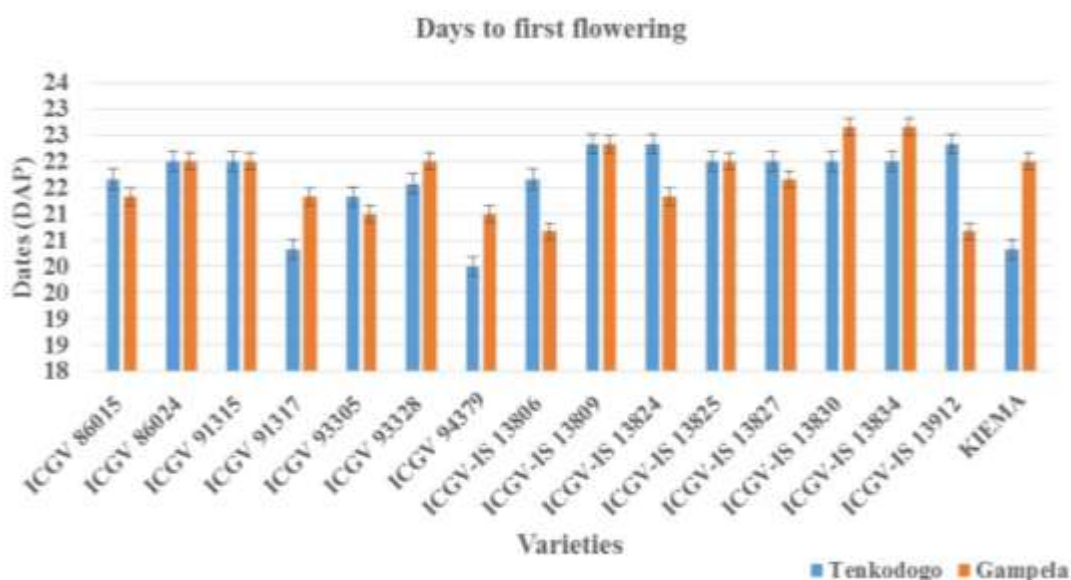


Figure 3. Days to first flowering at Tenkodogo and Gampela.

Tenkodogo (Table 2). At Gampela, the pods' yields ranged from $2394.99 \text{ kg}\cdot\text{ha}^{-1}$ (ICGV-IS 13806) to $1439.7 \text{ kg}\cdot\text{ha}^{-1}$ (ICGV 91317) with a mean of $1899.97 \text{ kg}\cdot\text{ha}^{-1}$. At Tenkodogo, the average pods yield was $1496.91 \text{ kg}\cdot\text{ha}^{-1}$. The highest pods yield was recorded by variety ICGV-IS 13912 ($1804.78 \text{ kg}\cdot\text{ha}^{-1}$) and ICGV 94379 recorded the lowest yield ($1160.72 \text{ kg}\cdot\text{ha}^{-1}$).

Shelling ratio and sorted seeds

Table 3 presents the shelling ratio of unsorted and sorted

seeds. There were significant differences between varieties for these parameters in all the sites for unsorted seeds. At Gampela the average shelling ratio was 71.59%. The means separation test revealed three groups. The first group constituted only the variety ICGV 93328 with a shelling ratio of 74.42%. The second group was composed of varieties ICGV-IS 13827, ICGV-IS 13806, ICGV 91315, KIEMA, ICGV-IS 13809, ICGV 86015, ICGV-IS 13825, ICGV 86024, ICGV-IS 13912, ICGV-IS 13834, ICGV-IS 13830, ICGV 91317 and ICGV-IS 13824; and the third composed of ICGV 93305 (68.55%).

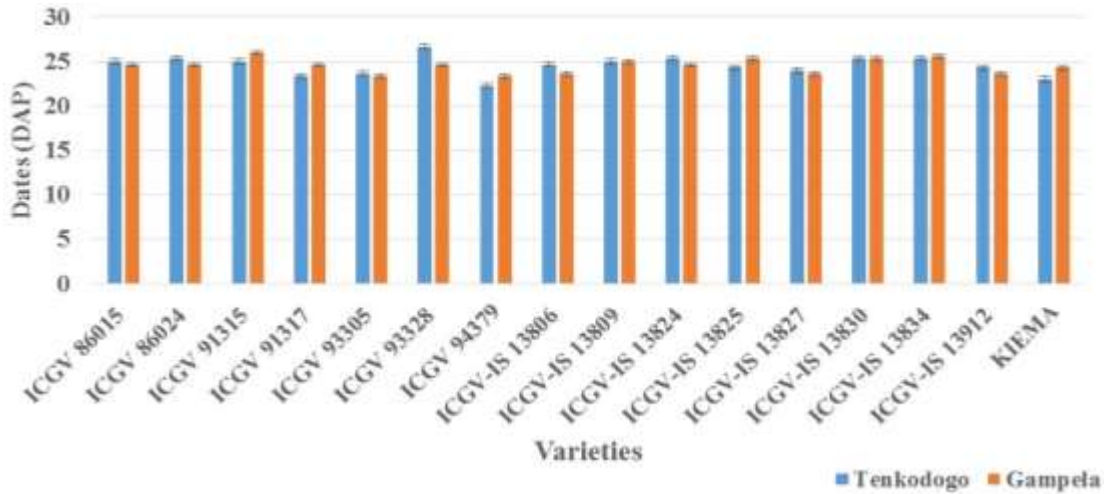


Figure 4. Days to 50% flowering at Tenkodogo and Gampela.

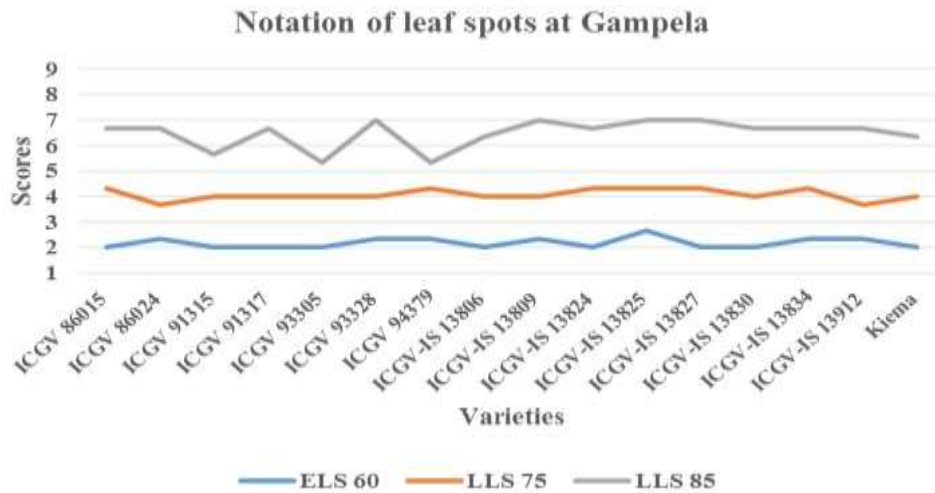


Figure 5. Scores of foliar diseases at 60, 75 and 85 DAP on groundnut varieties at Gampela

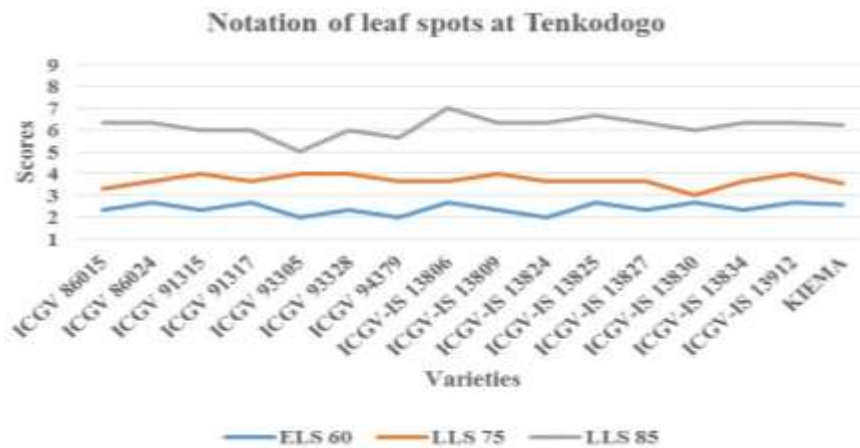


Figure 6. Scores of foliar diseases at 60, 75 and 85 DAP on groundnut varieties at Tenkodogo.

Table 2. Mean pods yields at Gampela and Tenkodogo.

Variety	Pods yields (kg.ha ⁻¹)	
	Gampéla	Tenkodogo
ICGV 86015	1961.38 ^{ab}	1458.33 ^a
ICGV 86024	2103.66 ^{ab}	1715.28 ^a
ICGV 91315	1710.70 ^{ab}	1259.33 ^a
ICGV 91317	1439.70 ^a	1176.25 ^a
ICGV 93305	1686.99 ^{ab}	1408.00 ^a
ICGV 93328	1688.35 ^{ab}	1258.56 ^a
ICGV 94379	1673.44 ^{ab}	1160.72 ^a
ICGV-IS 13806	2394.99 ^b	1687.78 ^a
ICGV-IS 13809	1802.17 ^{ab}	1361.11 ^a
ICGV-IS 13824	1785.23 ^{ab}	1712.78 ^a
ICGV-IS 13825	1942.84 ^{ab}	1732.33 ^a
ICGV-IS 13827	2222.22 ^b	1443.06 ^a
ICGV-IS 13830	1944.44 ^{ab}	1779.67 ^a
ICGV-IS 13834	2130.76 ^{ab}	1689.89 ^a
ICGV-IS 13912	2079.95 ^{ab}	1804.78 ^a
KIEMA	1832.66 ^{ab}	1302.78 ^a
Mean	1899.97	1496.91
CV (%)	16.58	20.16
P-value	0.005	0.009

CV: Coefficient of variation.

Table 3. Shelling ratio of unsorted and sorted seeds.

Variety	Shelling ratio of unsorted seeds		Shelling ratio of sorted seed	
	GAMPÉLA	Tenkodogo	GAMPÉLA	Tenkodogo
ICGV 86015	72.12 ^{ab}	66.20 ^a	61.70 ^b	26.45 ^a
ICGV 86024	71.97 ^{ab}	63.75 ^a	63.52 ^b	37.88 ^{abc}
ICGV 91315	72.72 ^{ab}	62.47 ^a	58.10 ^{ab}	30.87 ^{ab}
ICGV 91317	69.90 ^{ab}	59.17 ^a	47.20 ^a	33.90 ^{abc}
ICGV 93305	68.55 ^a	63.15 ^a	61.00 ^b	50.08 ^c
ICGV 93328	74.42 ^b	61.25 ^a	56.38 ^{ab}	35.77 ^{abc}
ICGV 94379	69.23 ^{ab}	63.82 ^a	62.05 ^b	34.60 ^{abc}
ICGV-IS 13806	72.83 ^{ab}	65.85 ^a	67.70 ^b	44.03 ^{abc}
ICGV-IS 13809	72.28 ^{ab}	62.77 ^a	61.03 ^b	33.60 ^{abc}
ICGV-IS 13824	69.65 ^{ab}	58.30 ^a	59.50 ^{ab}	28.15 ^a
ICGV-IS 13825	72.08 ^{ab}	66.37 ^a	65.02 ^b	43.65 ^{abc}
ICGV-IS 13827	73.47 ^{ab}	64.68 ^a	63.68 ^b	36.78 ^{abc}
ICGV-IS 13830	70.93 ^{ab}	62.25 ^a	61.47 ^b	33.10 ^{abc}
ICGV-IS 13834	71.22 ^{ab}	66.97 ^a	62.67 ^b	47.43 ^{bc}
ICGV-IS 13912	71.67 ^{ab}	65.43 ^a	60.28 ^b	31.23 ^{ab}
KIEMA	72.47 ^{ab}	57.10 ^a	61.87 ^b	29.33 ^{ab}
Mean	71.59	63.09	60.82	36.05
CV (%)	2.95	6.28	9.26	23.52
P-value	0.012	0.018	0.002	0.001

For the shelling ratio of sorted seeds, significant differences were observed between the varieties in

Gampela and Tenkodogo. At Gampela, three classes were distinguished. The first class composed of 12

Table 4. Variables by location interaction.

Location	Pods yields	Haulm yield	HSW	Shelling ratio of unsorted seed	Shelling ratio of sorted seed
Gampela	1899.97 ^b	2846.80 ^b	38.51 ^a	71.59 ^b	60.82 ^b
Tenkodogo	1496.92 ^a	2495.77 ^a	37.68 ^a	63.1 ^a	36.05 ^a
P-value	0.000	0.000	0.411	0.000	0.000

varieties: ICGV-IS 13806, ICGV-IS 13825, ICGV-IS 13827, ICGV 86024, ICGV-IS 13834, ICGV 94379, KIEMA, ICGV 8615, ICGV-IS 13830, ICGV-IS 13809, ICGV 93305 and ICGV-IS 13912 with shelling ratio varying between 60.28 and 67.70%.

At Tentodogo means separation test determined 5 groups. The first group was composed of the variety ICGV 93305 with 50.08%, the second group was composed of the variety ICGV-IS 13834 with 47.43%, the third group comprised varieties ICGV-IS 13806, ICGV-IS 13825, ICGV 86024, ICGV-IS 13827, ICGV 93328, ICGV 94379, ICGV 91317, ICGV-IS 13809 and ICGV-IS 13830 with shelling ratio ranging from 33.10 to 44.03%. The fourth group contained varieties ICGV-IS 13912 (31.23%), ICGV 91315 (30.87%) and KIEMA (29.33%) and the fifth group had two varieties ICGV-IS 13824 (28.15%) and ICGV 86015 (26.45%) which recorded the lowest shelling ratio.

Better shelling ratio of sorted seed was observed at Gampela with an average of 60.82% against 36.05% at Tenkodogo.

Genotype by location interaction

The results of combined analysis for pods yields, haulm yields, technological quality and grain maturity are presented in Table 4. Significant genotype by environment effects was observed for all the parameters except hundred seeds weight. The best performances were observed at Gampela except grain percentages M2 and M3.

Cluster analysis revealed three classes. Class one was composed of six varieties ICGV-IS 13825, ICGV 91315, ICGV 91317, ICGV 93328, ICGV-IS 13809 and ICGV 94379 with high percentage of grain maturity. Class two was composed of three varieties which are ICGV-IS 13830, ICGV-IS 13806, and ICGV-IS 13912 with high yield potential. Class three was composed of seven varieties (ICGV-IS 13824, KIEMA, ICGV 86024, ICGV-IS 13827, ICGV 93305, ICGV-IS 13834, and ICGV 86015) which have low aflatoxin content.

Aflatoxins contents of the varieties

The results of the aflatoxins contents in the two sites are presented in the Figure 7. In this study, the M1 grains are

generally less contaminated by aflatoxins than the M2 grains which are also less contaminated than M3 grains.

At Gampela, the varieties with low contents in aflatoxins are

(1) ICGV 86015, ICGV-IS 13824, ICGV-IS 13834, ICGV-IS 13912 and KIEMA from which the reader could not detect aflatoxins

(2) ICGV 91317 (M1= 0 ppb, M2= 0 ppb and M3= 0.1 ppb), ICGV 91315 (M1= 0 ppb, M2 = 0.9 ppb and M3 = 0 ppb), ICGV 93305 (M1= 0.5 ppb, M2 = 0.5 ppb and M3 = 0.8 ppb), ICGV 93328 (M1 = 0 ppb, M 2=1 ppb and M3 = 0.3 ppb) and ICGV-IS 13830 (M1 = 0.6 ppb, M2 = 0.6 ppb and M3 = 2 ppb).

The high contents aflatoxins varieties were ICGV 94379 (M1= 2.4 ppb, M2= 3 ppb and M3=3.2 ppb) and ICGV-IS 13809 (M1= 2.4 ppb, M2= 2 ppb and M3= 2 ppb).

At Tenkodogo site, the low aflatoxins contents varieties are ICGV-IS 13834 (M1 = 0 ppb, M2 = 0.3 ppb and M3 = 0 ppb), ICGV 93305 (M1= 0.5 ppb, M2 = 0.5 ppb and M3 = 0.8 ppb), ICGV-IS 13912 (M1= 0.3 ppb, M2 = 0.6 ppb and M3 = 1.2 ppb), ICGV 94379 (M1 = 1.7 ppb, M2 = 1.1 ppb and M3 = 1.1 ppb), ICGV-IS 13830 (M1 = 0.7ppb, M2 =1.2 ppb and M3 = 1.8 ppb).

The high contents aflatoxins varieties are ICGV 91317 (M1 = 3.3 ppb, M2 = 3.9 ppb and M3 = 3.3 ppb), ICGV 93328 (M1 = 2.9 ppb, M2 = 3 ppb and M3 = 3.3 ppb), ICGV-IS 13825 (M1 =2.2 ppb, M2 = 2.3 ppb and M3 = 2.6 ppb), ICGV 91315 (M1 = 2.8 ppb, M2 = 2.3 ppb and M3 = 2.1 ppb).

Percentage of maturity of pods and seeds

The statistical analysis shows no significant differences from the varieties in the two sites. But for the site of Gampela, the grain maturity is respectively 45.06% for M1, 26.24% for M2 and 28.4% for M3 and for the site of Tenkodogo, the values are 35.38% for M1, 31.45% for M2 and 33.18% for M3. In the two sites, the percentage of mature grains is higher than immature grains.

Discriminant analyzes

At Gampela, the ascending hierarchical classification grouped the varieties into three classes (Figure 8):

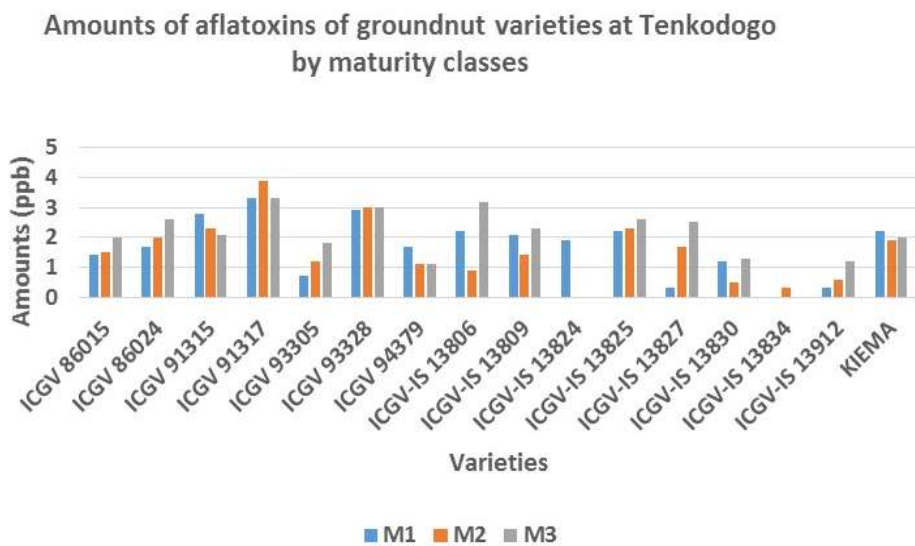
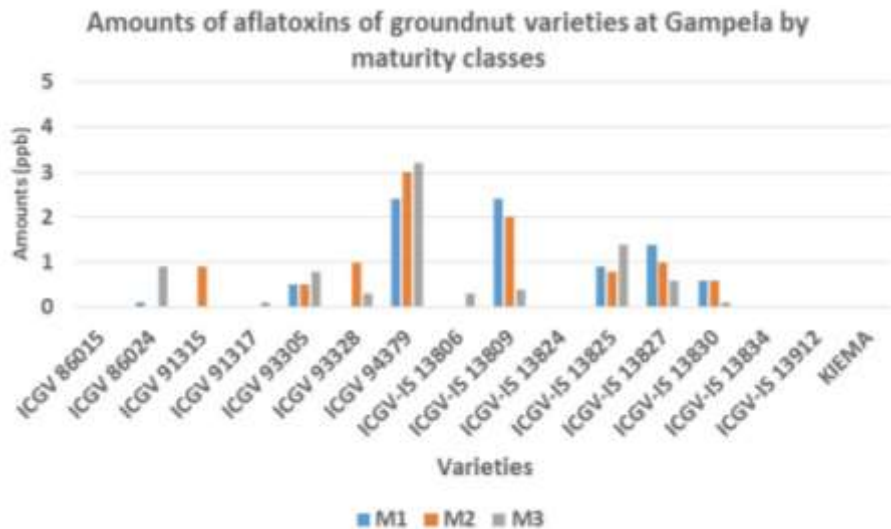


Figure 7. The contents of aflatoxins of the varieties by maturity classes at Gampela and Tenkodogo.

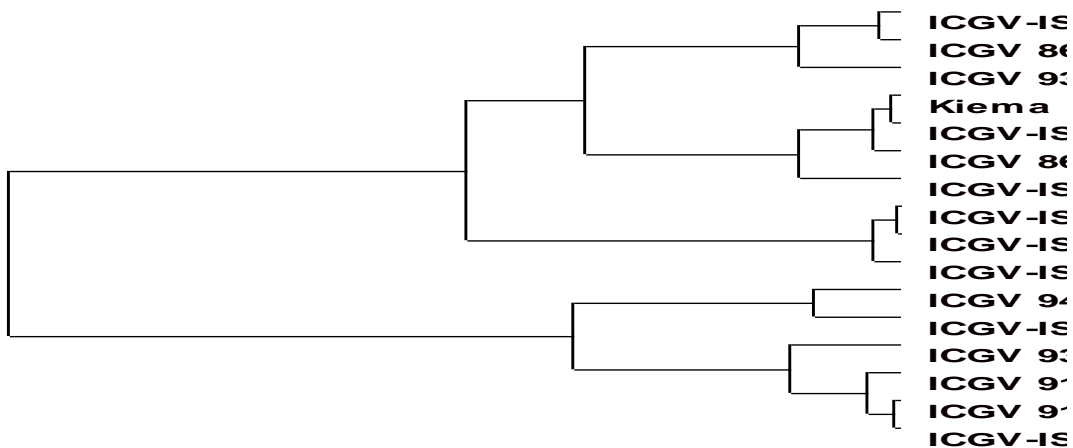


Figure 8. Dendrogram showing the varietal distribution at Gampela.

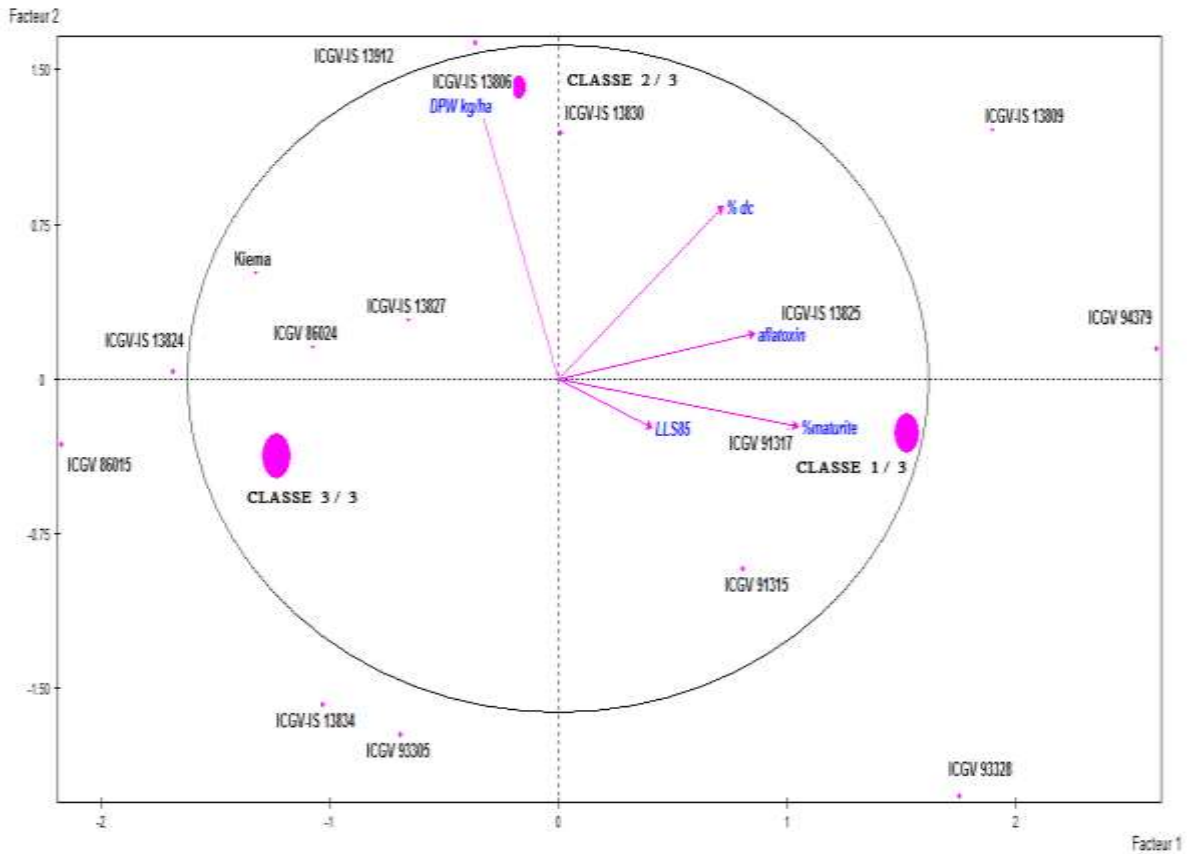


Figure 9. Distribution classes at Gampela.

(1) Class 1 includes 6 varieties, ICGV-IS 13825, ICGV 91315, ICGV 91317, ICGV 93328, ICGV-IS 13809, and ICGV 94379 which have a high percentage of maturity and are sensitive to aflatoxin.

(2) Class 2 consists of 3 varieties namely ICGV-IS 13830, ICGV-IS 13806, ICGV-IS 13912 which have good pods yields.

(3) Class 3 consists of 7 varieties ICGV-IS 13824, Kiema, ICGV 86024, ICGV-IS 13827, ICGV 93305, ICGV-IS 13834, and ICGV 86015 which are tolerant to aflatoxins.

At Gampela it was observed that the percentage of grain maturity was positively correlated to the aflatoxin content, shelling ratio and foliar diseases. Shelling ratio was positively correlated to pods yields. In contrast, pods yields were negatively correlated to foliar diseases pressure (Figure 9).

At Tenkodogo, the cluster analysis determined three classes (Figure 10). The first class was composed of five varieties (ICGV-IS 13824, ICGV-IS 13825, Kiema, ICGV 86024 and ICGV-IS 13806) which have good pods yields. Class two composed of four varieties: ICGV-IS 13830, ICGV-IS 13827, ICGV 93305, ICGV-IS 13834 characterized by their tolerance to foliar diseases and aflatoxin. Class three was composed of varieties ICGV-IS

13809, ICGV-IS 13812, ICGV 91317, ICGV 93328, ICGV 91315, ICGV 86015 and ICGV 94379 with a high percentage of maturity.

At Tenkodogo, there was positive correlation between percentage of grain maturity and shelling ratio, leaves spots and aflatoxins (Figure 11).

DISCUSSION

Emergence rate at 10 days after planting (DAP) showed a good emergence rate at Gampela (92.68%) and Tenkodogo (88.35%). This is due to the good land preparation, the use of quality seeds treated with Calthio C (insecticide-fungicide) and immediate sowing after good rainfall. These factors allowed to reduce seedling death and contributed to the good emergence (Martin et al., 1999). Variation in emergence rate observed between the varieties is related to the intrinsic parameters of each variety such as the physiological state of the seed, their degree of maturity and their sanitary status and that within seed of the same variety (NANA, 2009). The experimental site of Tenkodogo which has been in an on-farm trial conditions, the low emergence rate compared to

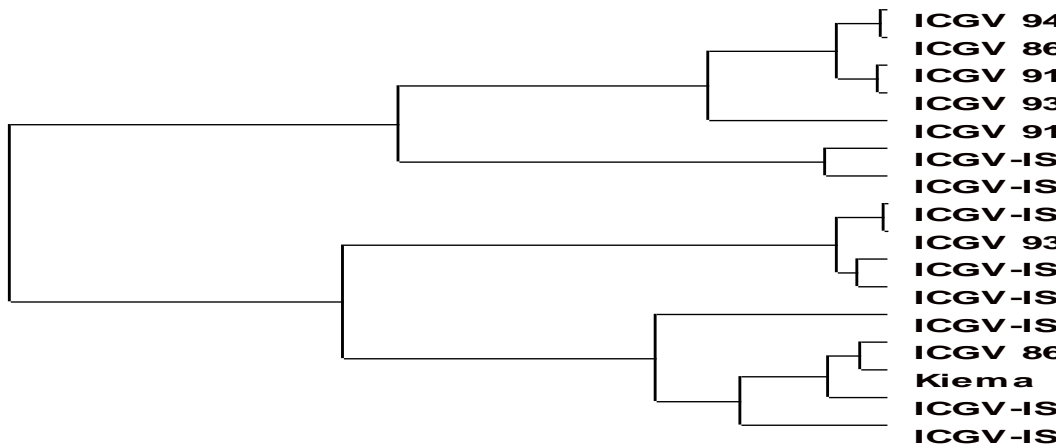


Figure 10. Dendrogram showing the varietal distribution at Tenkodogo.

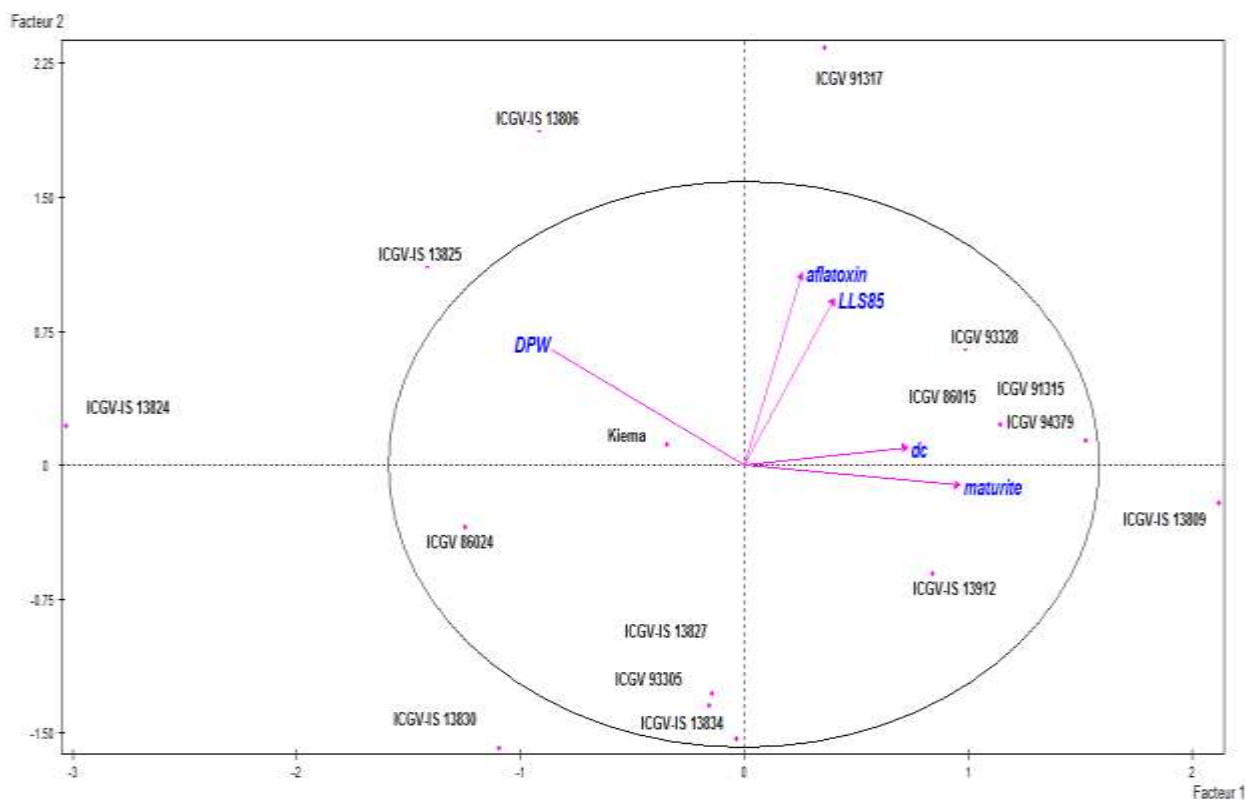


Figure 11. Distribution classes at Tenkodogo.

Gampela is related to empty hills uprooted by birds.

Days to first flowering is an indicator of earliness of a variety. The earlier a variety flowers, the earlier it will set pod and mature and then escapes terminal drought. As regards to this character, varieties ICGV 91317, ICGV 94379 and KIEMA could be the early flowering (20 DAP) across the two sites. They also reached 50% flowering

earlier than the others ICGV 94379 (22 DAP), ICGV 91317 (23 DAP) and KIEMA (23 DAP) on both sites. The result shows this character is more under genetic control than environmental factor. The other varieties reached days to 50% flowering in average on the 25th DAP. Variety ICGV 93328 appeared to be the latest flowering (27 DAP). This result shows that there is correlation

between days to first flowering and days to fifty percent flowering thus confirming the findings of Zagre (1994) who reported that these two characters are highly correlated. It was observed that all the varieties reached 50% flowering with three to five days inferring that they have grouped flowering time.

Regarding the scores of leaves spots, varieties had notes comprising 5 to 7 at 85 DAP, showing that all the varieties should be moderately sensitive to this disease (Subbrahmanyam et al., 1995; Amos et al. (2002). The first date of scoring (60 DAP) showed lower notes corresponding to the beginning of Early Leaf Spot (ELS) infection and the scores are very low as Miningou et al. (2002) reported in their paper.

The aflatoxins contents varied between the classes of maturity. The immature grains were more contaminated than the mature confirming the studies of Traore (2005) in Sénégal who showed that the immature grains were more contaminated than the mature. Then the M1 grains (very ripe) were less contaminated than the M2 grains (ripe) and these M2 grains were less contaminated than the immature M3 grains. The low contents of aflatoxins of the varieties less than 4 ppb for all classes of maturity from the two sites show the good agronomical management of the fields. This also shows that the good sorting of pods and grains can reduce very significantly the amount of aflatoxin of groundnut for consumption. The site of Tenkodogo appeared more contaminated by aflatoxins than Gampela site because the previous crop was maize (which favors the contamination of the next crop by *Aspergillus flavus/parasiticus*) while that of Gampela was sesame (less contaminated by *A. flavus/parasiticus* in the field than maize).

In the two sites, the aflatoxin contents of the varieties are relatively low (0-3.9 ppb). These levels comply with European standards (4 ppb for total aflatoxins) (Baht and Vashanti, 1999; FAO, 2003; Herry, 2003; USAID, 2012) and with American standards (20 ppb for total aflatoxins). These low levels are the result of strict compliance with good agronomic practices (date and density of sowing, weeding, fertilizer application, ridging, harvesting at the right time of maturity, drying ...) and sorting because the seeds have also been well sorted. These results are similar to those of Nikiema (1993), which showed that sorting is an effective way of reducing contamination. In view of these results, it is indeed possible to relaunch the cultivation of groundnuts for export with levels that meet international standards. Ahmet et al. (2011) analyzed some seed oils for their composition and characteristics and concluded that these seed oils were suitable for edible purposes as it contained relatively higher amounts of unsaturated fatty acid, very close to those reported for the edible oils. Musa and Serap (2003) analyzed also fatty acid composition of peanut, peanut oil and peanut butter from ÇOM and NC-7 cultivars and found that the major fatty acids of peanut seeds and butter of both cultivar were oleic, linoleic and palmitic acids. Both variety exhibited higher concentrations of oleic acid and

peanut seeds and butters of ÇOM and NC-7 were found rich in oil, protein, oleic and linoleic acids and mineral compositions. Also, the peanut butters are nutritionally equivalent to peanut kernel.

In order to be adopted by producers, varieties must have good technological characteristics such as good shelling ratio, medium to high weight of 100 seeds and less pods and seeds damaged. Varieties that would meet these criteria would be ICGV-IS 13824, ICGV-IS 13834 and ICGV-IS 13912.

For groundnut storage, Fahad et al. (2018) reported that acidity and peroxide values of raw and roasted NC-7 and ÇOM kernel oils increased during storage. The unsaturated fatty acids such as oleic, linoleic acids of roasted peanut oils gradually decreased during storage and that the highest linoleic acid were found in the initial periods of storage for raw and roasted NC-7 and ÇOM oils.

Higher pods yields were obtained at Gampela compared to Tenkodogo. This could be attributed to environmental conditions (sol, climate, parasite pressure). The major edaphic constraints at Tenkodogo could be related to their poorness in nutritive minerals (N, P, and K). The immediate consequence could be a bad pod filling leading to low yield (Gillier and Silvestre, 1969).

For shelling ratio (unsorted seed), the mean percentage was above 60% in both sites. Zongo (2012) reported an average percentage of 58.39% at Gampela. Difference of yield between unsorted seeds and sorted seeds comes from the sorting of immature and damaged grains. Percentage of sorted seed was higher at Gampela than Tenkodogo. This could be due to the degree of maturity of seeds and their physical state (damaged seeds) as well. These results corroborate those of Taita et al. (1996) who reported that water stress at the end of the cycle combined to the progression of leaves spots are responsible of bad pod filling. In these conditions, the pods do not reach their optimal physiological maturity engendering rough grains. At Tenkodogo, the low shelling ratio of sorted seeds is also due to pods attacks by termites and millipedes reducing the number of good grains and resulting in low shelling ratio after sorting.

There was a negative correlation between the percentage of maturity and the aflatoxins contents and positive correlation between the percentage of maturity of grains and the shelling ratio in the two sites. This result showed that an early sowing conducts to a good filling of the pods and less contamination by aflatoxins. There was also a positive correlation between shelling ratio and pods yields leading to the fact that when the pods are full they weigh more and increase the yield.

Environmental effects were noted on the following parameters: pod and haulm yields, shelling ratio (unsorted and sorted grains). These parameters varied from Gampela to Tenkodogo because the differences between the two locations were highly significant.

Conclusion

This study permitted to assess the agronomic performance and the level of tolerance of sixteen (16) varieties of groundnut to aflatoxins according to the location. The average pods yields were above 1 ton in the 2 locations. The best yields were observed from ICGV-IS 13806 (2394.97 kg.ha⁻¹) at Gampela and ICGV-IS 13912 (1804.78 kg.ha⁻¹) at Tenkodogo. In conditions of water deficit at the end of the cycle, varieties tolerant to water stress would have a better capacity for maturation, thus limiting aflatoxins contamination. According to the location, the varieties do not present the same level of aflatoxins contamination. In the two locations, the variety ICGV-IS 13834 would be the most tolerant to aflatoxins. Aflatoxin levels are higher in Tenkodogo than in Gampela. This may result from the influence of edaphic and climatic factors. The negative correlation between the percentage of maturity of grains and the aflatoxins contents and the positive correlation between the percentage of maturity of grains and the shelling ratio indicates that an early sowing allowed good filling of pods and then the very significant reduction of aflatoxins contamination. The positive correlation also between the shelling ratio and the pods yields shows that the more the pods are full the more they weigh and increase the yield.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests

ABBREVIATIONS

DAP, Day after planting; **kg.ha⁻¹**, kilogram per hectare; **MED**, Ministère de l'Economie et du Développement; **ICRISAT**, International Crops Research Institute for Semi-Arid Tropics; **ICGV**, ICRISAT groundnut variety; **IDR**, Institut du Développement Rural; **NPK**, nitrogen-phosphorus-potassium; **INERA**, Institut de l'Environnement et de Recherches Agricoles; **ELISA**, enzyme-linked-immunosorbent-assay; **ELS**, early leaf spot; **LLS**, late leaf spot; **FAO**, Food and Agricultural Organization; **USAID**, United States Agency for International Development.

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