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RESEARCH ARTICLE

MORPHO-PHYSIOLOGICAL AND AGRONOMICAL RESPONSE TO INTERMITTENT DROUGHT IN GROUNDNUT GENOTYPES UNDER SAHELIAN ENVIRONMENT

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Abstract

Selection of groundnut genotypes with high and stable grains yield in the semi-arid tropics would enable farmers to increase yields and improve their incomes. The objectives of this work were to assessgroundnut genotypes response toan intermittent water deficit at the seed filling phase and select drought-tolerant and high-yielding genotypes. Two experiments were conducted in two yearsduring off-seasons at the ICRISAT Sahelian Centre.Fourteen genotypes were assessed in adjacent terminal water-stressed (WS) and well-watered (WW) conditions in a randomized complete block design with four replications. Morpho-physiological parameters such asthe leaf area (LA)and the Specific Leaf Area (SLA), the yield and its components were investigatedunder WW and WS conditions.Our findings showed a genotypic variationand a significant negative effect of WS on investigated parameters. LA, SLA, HY, SY, HSW and HI were decreased up to 48.59%, 25.29%, 30.14%, 51.70%, 21.17% and 23.80% respectively.The genotypic variation observed indicated that ICG 311,ICG 4598,ICG 5663, ICG 6813 and ICG 12235produced the highest and stable yields underintermittent water deficit.These genotypes could be useful for groundnut breeding programs for selecting improved genotypes tolerant tolate season intermittent drought and high grain yield under Sahelian conditions.

Introduction:-

Groundnut (*Arachis hypogaea* L.) is an important cash crop in the semi-arid tropics where drought is a major constraint (Dramé et al., 2007). It is the second most important legume crop after cowpea (*Vigna unguiculata* L.) in Niger (Hampson et al., 2001). Groundnut grown in the Sahel often experiences water deficits during the pod-filling phase, which usually coincides with the end of the rainy season (Ndunguru et al., 1995). Drought during the pod filling phase is common and causes the greatest reduction in peanut pod Yield.Also previous study reported that terminal drought stress may reduce pod yield by up to 35% and biomass by 21%(Girdthai et al., 2010). Other

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previous works reported that some physiological traitssuch as leaf area index (LAI), specific leaf area (SLA), SPAD chlorophyll meter reading (SCMR) and stomatal conductance are related to drought tolerance in groundnut(Koolachart et al., 2013).SLA was associated with variation in photosynthetic capacity and chlorophyll density expressed as high SCMR (Rao et al., 1985). SCMR was directly related to the amount of chlorophyll in the leaves of groundnut(Akkasaeng et al., 2003). Breeding for drought tolerance has been an important strategy adopted by researchers to alleviate the water stress problems and to ensure the production in environments prone to drought (PEREIRA et al., 2012).Researchers have attempted to improve performance by selecting plants with good yield under drought conditions in order to enable stability of production (de Lima Pereira et al., 2015). In environments where water availability is deficient, up right cultivars represent an important alternative to farmers due to short cycle and low water requirement during the growth (Painawadee et al., 2009). The previous investigations were carried out mostly under early season drought and prolongeddrought (Akbar et al., 2017; Bacharou Falke et al., 2019). However, sufficient investigations were not carried out under intermittent drought during seed filling phase. Also, it is essential to identify water deficit sensitive developmental stages to minimize damage caused by drought. Moreover, selection for high SCMR and low SLA under late season drought conditions is expected to have a greater effect on *Aspergillus. flavus* infection and pre-harvest aflatoxin contamination than selection for the other drought resistance traits(Girdthai et al., 2010). Thus, this study aimsto contribute to the development of groundnut genotypes that can tolerate water deficit during the critical reproduction period for sustainable production in the drought-prone regions.

The specific objectives were therefore,(i) assess the groundnut genotypes for intermittent drought tolerance during seed fillingin the field conditions and (ii) identify relevant drought tolerantgenotypes and related traits for groundnut breeding programs.

Materiel and Methods:-

Genotypes and experimental conditions

The genotypes used in this studywere selected from ICRISAT's groundnut mini-core and provided by ICRISAT Niamey Regional genebank. These include ICG 6813, ICG 12235, ICG 4598, ICG 14523, ICG 3992, ICG 4684, ICG 5663, ICG 311, ICG 1668 andICG 15233 which are contrasting forresistance to aflatoxin contamination. The cultivars55-437 and JL24, used as checks,were resistant to pre-harvest aflatoxin contamination and susceptible to pre-harvest aflatoxin contamination respectively (Waliyar and Bockelee-Morvan 1989).In addition, J11originated from India was used because of its wide adaptation in the dry zone of West Africa whileFleur11considered as good tolerant to drought (N tare et al. 2003).

Two experiments were conducted with abovegenotypes were carried out in off-seasons 2019 and 2020 under field conditions at the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) Sahelian Centre in Sadoré (45km south of Niamey, Niger, 13°N, 2°E).The soil was sandy with very low organic matter content.

During the cropping period, the mean temperature (minimum and maximum) varied from 20.1°C to 41.8°C in year1 and 26.1°C to 43.5°C in year2while the relative humidity varied from 24% to 79% in year1 and from 42% to 81% in year2. The total water received from rainfall and irrigation was 435 mm and 355 mm respectively in WW and WS in year1 and 520 mm and 380 mm in year2.

Experimental design and water treatment

The experimental design was alpha lattice with two factors, water treatment as main factor and genotypes as sub-factor randomized in each water treatment with four replications. Within each replication, there were fourteen elementary plots(2m x 1 m)distanced with1 m. The water treatments were well-watered (WW) consisting of well irrigation ofplants until harvest (twice a week) and an intermittent water-stressed (WS) consisting of skipping irrigation. All plants were under WW treatment until the 60th day after sowing when WS imposed to water deficit plots. WS imposition consisted of skipping irrigation until the majority of WSplants showed clear wilting symptoms before watering and then stopping irrigation again (Hamidou et al., 2012). This cycle continues until the pod maturity.

Crop management

In each experiment, three seeds were sown by hand in each hill(3 cm deep)after receiving an irrigation of 30 mm using a Linear-move irrigation system (Valmont Irrigation Inc., Valley, Nebraska, USA). Two and three weeks after sowing, plants were thinned to two and one plants respectively. Plots were subsequently fertilized with 150 kg ha^{-1}

N-P_2O_5-K_2O and irrigated with 30 mm of water. The fields were kept free from weeds manually and insect pests were controlled by regular spraying of deltamethrin (Decis), Emacot and Benji.

Measurements:-

Theflowering date was recorded when 50% of plants in each plot reached flowering time. Theday to 50% grain filling stage was monitoring to applied water stress and days to maturity were recorded when 50% of plants in each plot showed matured pods(Hamidou et al., 2012).

Leaf Area (LA) was recorded using the leaf area meter (Leaf Area Meter LI-3100, LI-COR Inc., Lincoln, Nebraska 68504-0425, USA).Leaves were oven-dried at 70°C for 48 hours and weighed to determine the leaf dry weight (LDW) and the specific leaf area (SLA) which wasan indirect measure of leaf expansion andone of the physiological traits in plant analysis which is defined as the ratio of leaf area to leaf dry weight. Highvalues of SLA indicate high leaf area per unit biomass and hence larger surface area for transpiration(Hugar, 2017).

Specific Leaf Area was calculated as SLA (cm^2g^{-1}) $=\frac{\text{leaf area}}{\text{leaf dry weight}}$

At maturity, plants were harvested and, haulm and podsweight were determined.Haulm and pods weights obtained per plot ($g\ m^{-1}$) were extrapolate to determine haulm and pod yields into $g\ m^{-2}$.

Harvest index (HI) was determined as a ratio of adjusted pod weight to total biomass, given as: HI=$\frac{(1.65\times \text{Py})}{\text{Bt}}$

Statical Analysis

The data used were the means of the two years experimentsandanalyzed using GenStat 14th edition (VSN International Ltd, Hemel Hempstead, UK). Analyses of variance (ANOVAs) were run to test the genotype, water treatment and their interactions effects on the studied parameters. One-way ANOVA was used to evaluate the genotypic differences within each water treatment for the variables tested. Means were separated using an F-protected LSD at P = 0.05.

Results:-

Morpho-physiological traits

Genotypeand water treatment interaction (G×W) was significant (P<0,001) for leaf area(Table1).Thus, under treatment WW, the highest leaf area was observed on ICG 6813 (5222 cm²), Fleur11 (5151 cm²),ICG 4598 (4792 cm²), and ICG 12235(4731 cm²) while ICG 4684 (2118 cm²), ICG 15233(2262 cm²)and ICG 311 (2671 cm²) showed the lowest LA (Figure1).However, no significant G×W was observedfor SLA (Table1).Under both WW and WS, the highest SLA was observedonICG 14523 (128.68 $cm^2.g^{-1}$), ICG 4598 (127.21 $cm^2.g^{-1}$)and ICG 12235 (117.23 $cm^2.g^{-1}$), whereas ICG 5663 (88.44$cm^2.g^{-1}$), ICG 15233 (101.18 $cm^2.g^{-1}$), and JL24 (101.36$cm^2.g^{-1}$) showed the lowest SLA (Figure2).

Under WS condition, ICG 12235 (31688 cm^2), ICG 4598 (2990 cm^2) and ICG 3992(2456 cm^2) obtained the highest leaf area. While, ICG 4684 (1246 cm^2), ICG 311 (1493 cm^2) and ICG 1668 (1322 cm^2)showed the lowest leaf area. The highest SLA under WS was observed on ICG 12235 (102.44 $cm^2.g^{-1}$), ICG 3992 (98.76 $cm^2.g^{-1}$) and 55-437 (94.69 $cm^2.g^{-1}$) whereas ICG 5663 (61.52 $cm^2.g^{-1}$), JL24 (62.09 $cm^2.g^{-1}$), and ICG 311 (71.36 $cm^2.g^{-1}$) showed the lowest SLA (Figure2).WS imposed has negative effect on all measured traits (Table 2).

Table 1:- Results of variance analysis of morpho-physiological and yield traits.

Sources of	LA		SLA		HY(gm^{-2})		SY(gm^{-2})		100SW (g)		Harvest Index	
Variance	WW	WS	WW	WS	WW	WS	WW	WS	WW	WS	WW	WS
G	<.001***		0.002**		<.001***		<.001***		<.001***		<.001***	
W	<.001***		<.001***		<.001***		<.001***		<.001***		<.001***	
G×W	<.001***		0.870ns		0.909ns		<.001***		<.001***		<.001***	

Ns,*, and ***= non-significant at 5% level, significant at p<0.05 and significant at p<0.001 respectively.

Table 2:- Variation of morpho-physiologic traits under wellwatered (WW) and water stress (WS) treatments. Values are means of 4 replications.

Traits		WW	WS	WS negative effect (%)
Leaf area (cm^2)		3739.31±1367	1921.81±823	49

Specific leaf area ($cm^2 \cdot g^{-1}$)	109.51±30.58	81.83±26.42	25
Haulm yield ($g.m^{-2}$)	297.19±164.63	206.83±111.83	30
Seed Yield ($g.m^{-2}$)	114.31±39.60	55.18±24.59	51
Hundred seeds weight (g)	36.21±7.40	28.34±7.80	21
Harvest index	0.42±0.12	0.32±0.13	24

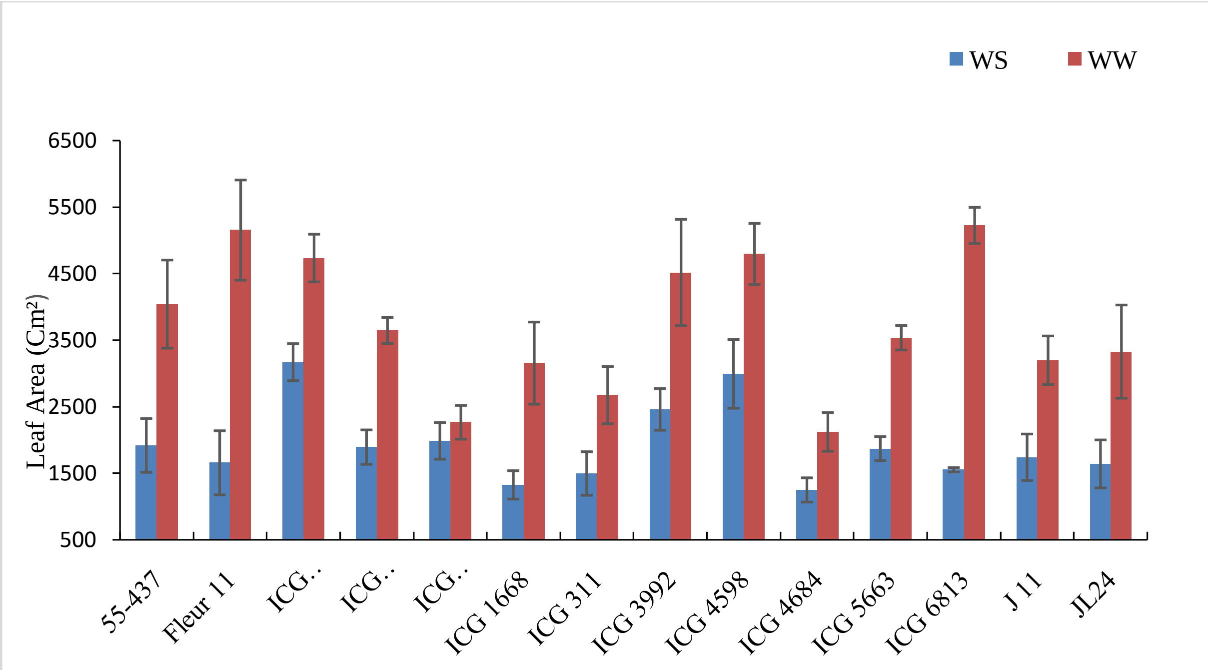

Figure 1:- Leaf area (LA)of 14 groundnut genotypes under well water (WW) and water stress (WS) treatments.

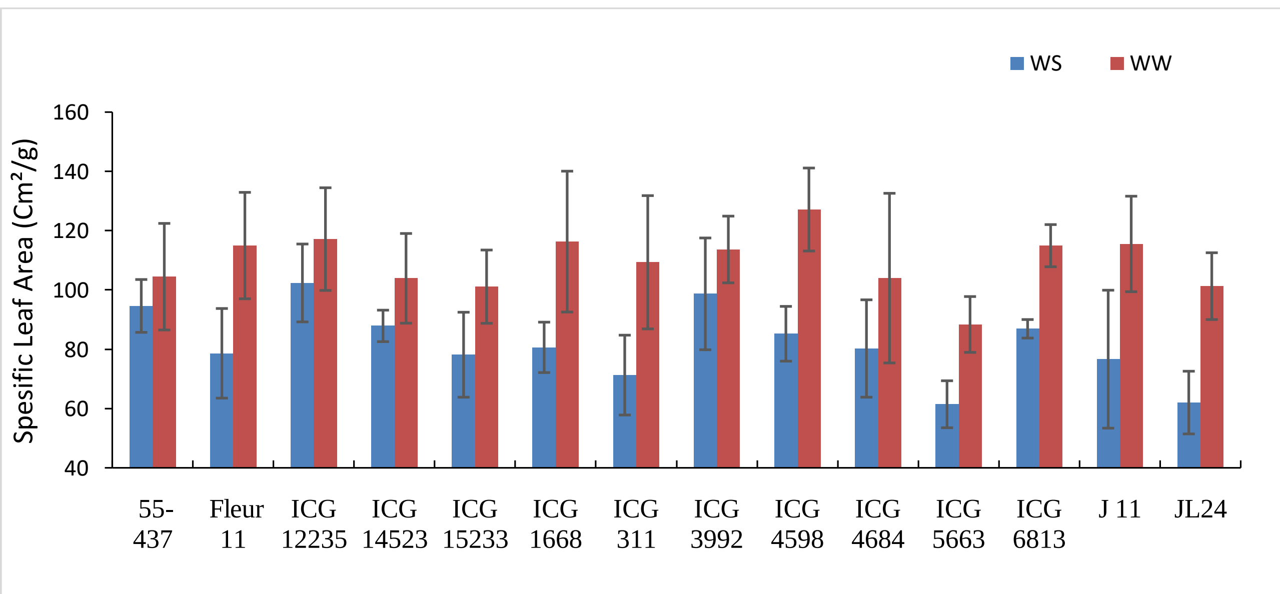

Figure 2:- Specific leaf area (SLA) of 14 groundnut genotypes under well water (WW) and water stress (WS)regimes.

Yield and its components under WW and WS conditions

There was significant G×W for allyield traits except the haulm yield (Table1). The highest haulm yield was observed on ICG 12235 (333.2 gm^{-2}), ICG 14523 (331.2 gm^{-2}), ICG 4598 (331.1 gm^{-2})and ICG 6813 (327gm^{-2})

under the two water treatments (Figure3).While the lowest was observed on55-437 (122.4gm^{-2}), ICG 4684 (138.4 gm^{-2}), ICG 311 (155.7gm^{-2}), and Fleur11 (162.5gm^{-2}). For the performance fin inseed yield, genotypesICG 4598 (159.37 gm^{-2}), Fleur11 (142.95gm^{-2}), and ICG 3992 (141.71gm^{-2}) revealed the best and ICG 12235 (50.11gm^{-2}), ICG 311 (86.44gm^{-2})and ICG 15233 (91.34gm^{2}) showed the lowestseedyield (Figure4). The highest 100 seed weight was showed by ICG 4598 (46.19 g) ICG 14523 (42.47 g)and JL24 (41.92g). The lowest 100 seeds weight was observed on 55-437 (29.5 g), ICG 12235 (29.89 g) and ICG 5663 (29.99 g)(Figure5). Our finding showed the highestHIon Fleur11 (0.56), 55-437 (0.47), and ICG 311 (0.49) and the lowest on ICG 12235 (0.22), ICG 6813 (0.37), JL24 (0.37)(Figure6).

Under WS,highest SY were showed by ICG 6813 (112.75gm^{-2}), ICG 14523 (72.21gm^{-2})and J11 (71.23gm^{-2})whereasICG 12235 (37.6gm^{2}),ICG 1668 (23.58gm^{2}) and ICG 3992 (33.37g.m^{2}) showed the lowest SY. For the hundred seeds weight, the highestwas observedonICG 4598(42.37g),ICG 311(33.28g) and ICG 14523(32.86g) and the lowest on ICG 1668(17.17g), ICG 15233(17.26g) and ICG 4684 (25.60g).High HI wasshown by 55-437 (0.47), ICG .4684 (0.44), and J11 (0.39). While ICG 1668 (0.16), ICG 3992 (0.18), ICG 12235 (0.21)showed the lowest HI.

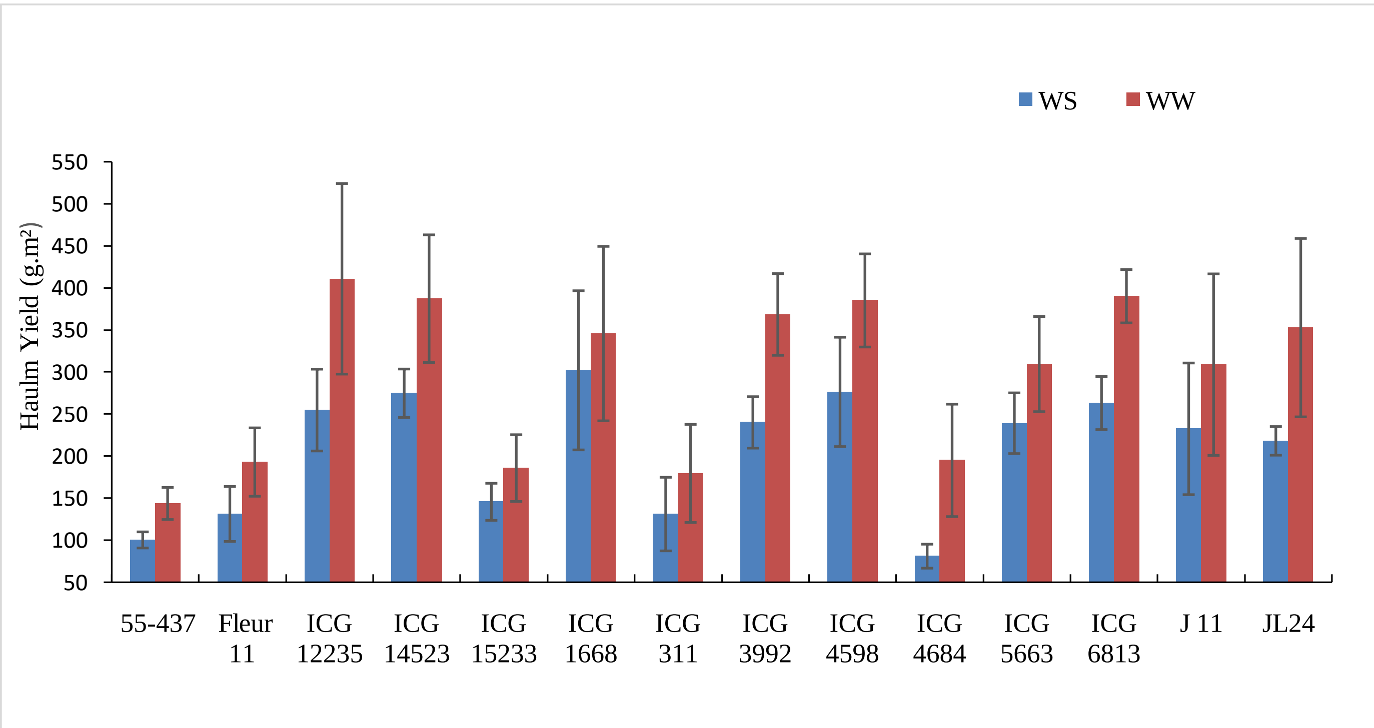

Figure 3:- Haulm yield of 14 groundnut genotypes under well water (WW) and water stress (WS) regimes.

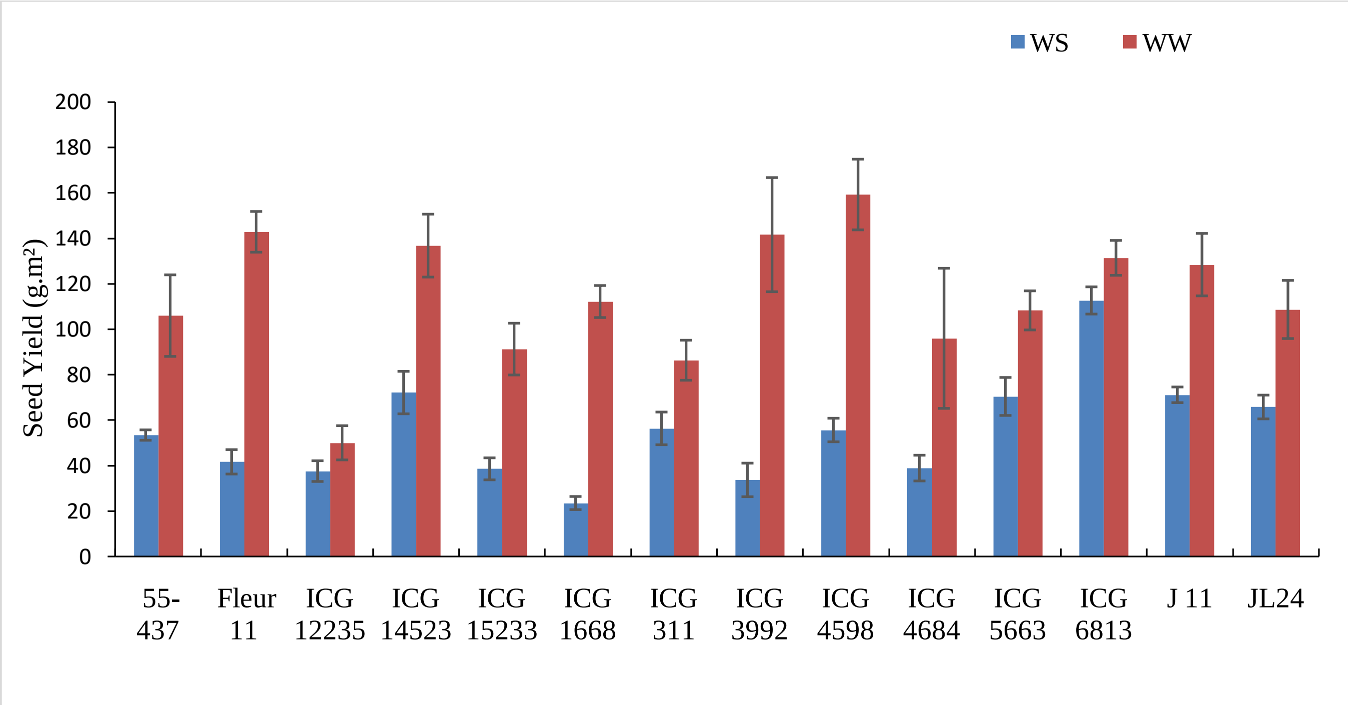

Figure 4:- Seed yield of 14 groundnut genotypes under well water (WW) and water stress (WS) regimes.

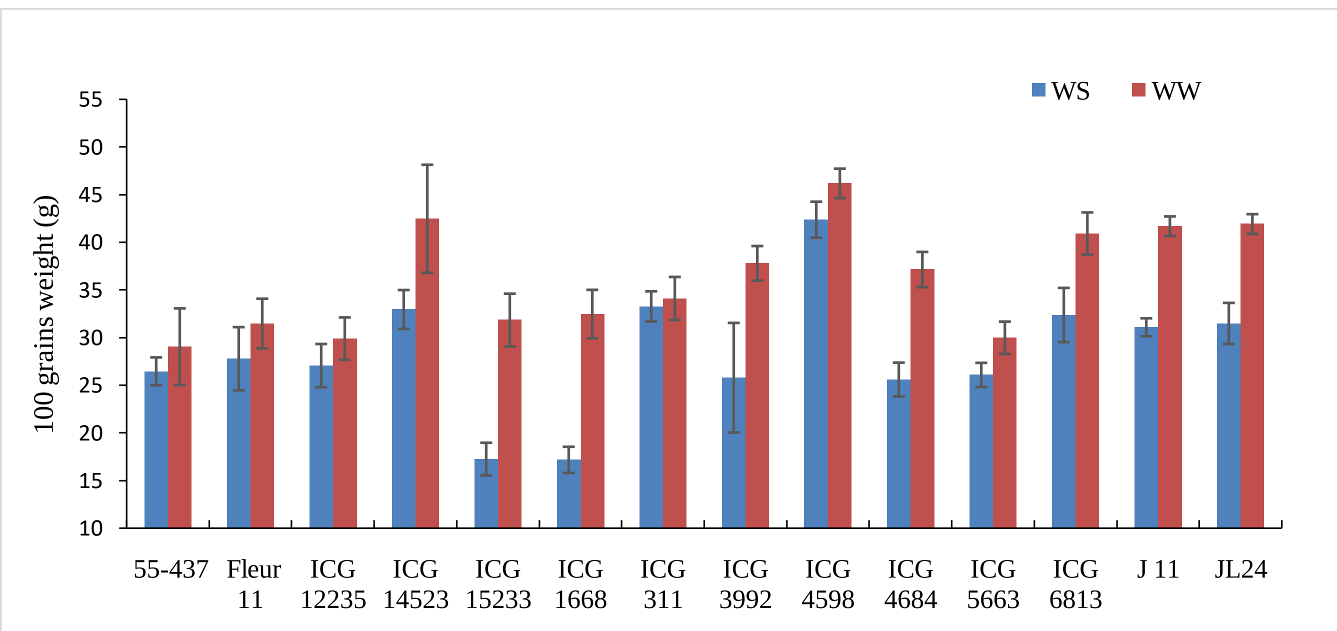

Figure 5:- Hundred seeds weight of 14 groundnut genotypes under well water (WW) and water stress (WS) regimes.

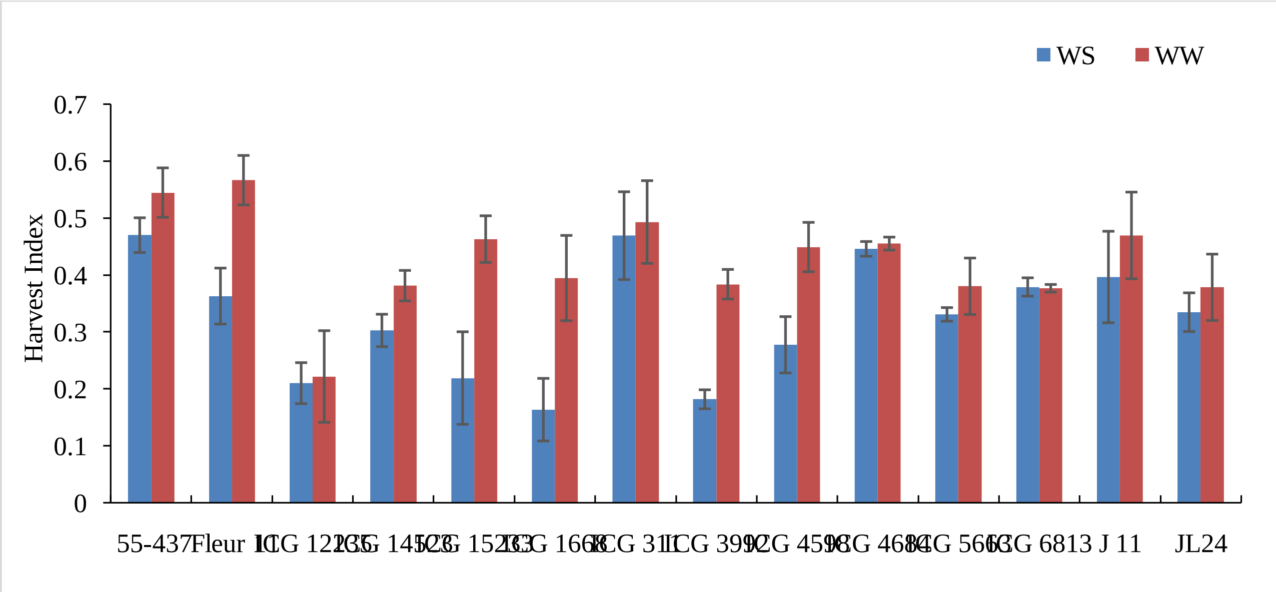

Figure 6:- Harvest index of 14 groundnut genotypes under well water (WW) and water stress (WS) regimes.

Discussion:-

Intermittent water deficit imposed fromgrains filling stageto maturity had reduced significantly almost studied traits.Indeed, Leaf area (LA), Specific Leaf Area (SLA), Haulm Yield (HY), Seed Yield(SY), Hundred Seed Weight (HSW) and Harvest Index (HI) were reduced up to 48.59%,25.29%, 30.14%, 51.70%, 21.17%, and 23.80% respectively. Ours findings showed that LA and SY were more severely affected by WS than other traits.Thedecrease of LAunder WS could be explained bythe decrease of plant water potential, leading to a reduction in the rate of cell division, cell walls rigidity (Granier et al., 2000), and the turgor decrease resulting in a shortening of growth in general and canopy expansionin particular ;Cosgrove, 2005; Bouchabke et al., 2006).Thus, the LA decrease, due to WS, of the early maturity genotypes such asICG 311 (78.90%), Fleur11 (67.88%), JL24 (50.79%) and 55-437 (52.58%) was less than the decrease of late maturity genotypessuch as ICG 15233 (12.33%), ICG 12235 (33.03%) and ICG 4598 (37.60%). These results were in concordance with previous studies which reported that the leaf area decreased under water deficit in groundnut at reproduction stage through a reduction of leaf number and leaf expansion(Samsukumar, 1991). Previous works reported also that theleaf area is one of the growth characters mostly affected by intermittent water deficit (Bacharou Falke et al., 2019; Kalariya et al., 2017; Ramana Rao, 1994; Ravindra et al., 1990; Tardieu et al., 2006). Our findings showed also thattwo genotypes ICG 4598 and ICG 12235 which maintained high leaf area under WS had the highest SLAindicating that late maturity genotypes kept more LA and SLA than early maturingunder WSduring grains filling phase. It was reported thatunder drought conditions, deposition of cuticle on the leaf surface increased leaf weight and is one of the causes of reduced LA resultingin higher leaf thickness(Kalariya et al., 2017).The significant G×W interaction for yield traits indicates that they were affected differently by water stress. Thus, grains yield (51.70%) was more affected by WS than HY (30.14%), 100 seeds weight (21.17%) and HI (23.80%).These results were in agreement with previous studies whichdemonstrateda significant yield loss due to water deficit during 60–85 DAS indicating that the sequence of growth stages from beginning seeding to beginning maturity is highly susceptible to water deficit conditions(Kalariya et al., 2017).Previous studies reportedalso that water deficit during the last month of groundnut cycle generally reduced pod weight, seed weight and harvest index(Boontang et al., 2010; Girdthai et al.,2010; Koolachart et al., 2013).Although they were negatively affected, genotypesICG 311, ICG 4598,ICG 5663, ICG 6813 and ICG 12235 showed high yield under drought indicating that theyrevealed droughttolerantas they showed an ability to partition dry matter into harvestable yield under limited water supplywhich is an important trait for drought tolerance(Nigam et al., 2005; Songsri et al., 2008).Previous study reported similar results and argued that high-yielding cultivar that continues to produce well under drought conditions is a priority to enable stability of production (De Lima Pereira et al., 2016).The reduced PY and 100 seed weight due to water deficit stress imposed during 60–85 DAS in this study could be explained by the impaired pod development followed by poor seed filling because of lack of moisture in the pod zone(Kalariya et al., 2017).ICG 311, ICG 4598, ICG 5663, ICG 6813 and ICG 12235 which revealeddrought tolerant and the tolerant check55-437 showed a low 100 seeds weight loss under WS. These findings revealed that the intermittent water stress during the grains filling phase reduced the finalseeds weight.Similarresults were observed byKalariya et al. (2017) andReddy et al.(2003).Thelow decrease of HI under WS can be explained by the great capacity of these genotypes to portioning dry matter because HI depends more on haulm yield than pods yield (Chapman et al., 1993; Nigam et al., 2005; Ong, 1986).Furthermore HI has been identified as a drought tolerance trait in peanut(Nigam et al., 2002).However, ICG 311, ICG 6813, ICG 3992, ICG 4684 showed the highest stability of harvest index (HI) in this study.These findings are in agreement with the previous results which reported that yield components and physiological traits are useful as selection criteria for pod yield under drought conditions(Koolachart et al., 2013).

Conclusion:-

Morpho-physiological and yield traits were used in this study to assess peanut genotypes response to intermittent drought during seed filling phase. The water deficit imposed affected negatively all parameters andwas more severe on leaf area and seed yield up to a decrease of 48.59% and 51.70% respectively. The genotypes ICG 311, ICG 4598, ICG 5663, ICG 6813 and ICG 12235which showed high LA, SLA, HY, SY, HSW and/or HI wereidentified as tolerant to intermittent water stress during reproduction stage ingroundnut cycle. These drought tolerance related traits could be used in breeding program to improve yieldin groundnut under Sahelian environment.

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