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# Influence of Temperature Regimes on Drought stress Tolerance of Cowpea Genotypes in Northern Guinea Savannah, Nigeria

**Indabo, S. S.[2], Muhammad, H. U[2]., Aliyu, A.[1], Sakariyahu, S. K.[2], Ahmed, H. O.[3] *Aliyu, R. E.[1]**
[1]Department of Botany, Faculty of Life Sciences, Ahmadu Bello University, Zaria
[2]Department of Biology, Faculty of Life Sciences, Ahmadu Bello University, Zaria
[3]Department of Plant Science, Institute for Agricultural Research, Ahmadu Bello University, Zaria
*Corresponding author: s.ramatu@gmail.com, enehezeyi@gmail.com

## ABSTRACT
Drought is a major constraint that affects cowpea production in Zaria, Nigeria. It is unpredictable, and occurs at any growth stage of cowpea. Changes in global climatic trends are consistently narrowing the cowpea growing season in Northern Nigeria by gradually pushing its cultivation towards drought-prone, colder temperatures. The study aimed to elucidate foresight data on the tolerance of cowpea landraces to drought at cold and hot temperatures in a bid to harness available germplasm towards mitigating climatic changes. Seedling drought tolerance of four hundred and twenty-two (422) cowpea genotypes obtained from farmers' collection (308) and the International Institute of Tropical Agriculture (IITA) (114) was evaluated by adopting the wooden box method. The parameters evaluated were number of plants, plant height, number of trifoliate, leaf senescence, stem greenness, and recovery. The mean square values for all evaluated traits were significant ($p \leq 0.05$). Leaf senescence progressed rapidly in cooler temperatures (6 $^{o}$C - 18 $^{o}$C). Interestingly, the recovery rate upon reintroduction of water after drought stress was higher in cold temperatures. The percentage recovery and stem greenness of drought-tolerant plants were positively associated with hot temperatures (22 $^{o}$C - 36 $^{o}$C). As cowpea production is pushed into colder planting season, the resilience shown by cowpea landraces in northern Nigeria are positive.

**Keywords*:*** Drought stress; Cowpea; Drought tolerance; Landrace; Temperature regimes

## INTRODUCTION
Drought is one of the major agricultural disasters globally. In Asia and Africa the production losses due to drought exceed the total losses caused by other environmental stresses (Cui *et al*., 2020). Considerable variation has been found in drought tolerance among cowpea varieties and at different stages of crop growth (Qin *et al*., 2018; Cui *et al*., 2020). Drought can occur at any time during the planting season and significantly affects the yield of cowpea. Damage to cowpea production is more severe when drought occurs at the vegetative stage (Qin *et al*., 2018; Nadeem *et al*., 2019). Studies have indicated that cultivars that are drought tolerant at vegetative stage have the potential to exhibit drought tolerance throughout their life cycle with a reasonable level of yield (Cui *et al*., 2020). Cowpea is a grain legume that is widely adapted to a variety of climatic and soil types. It is highly adapted to West Africa especially in warm climates (Anyia and Hergoz, 2004; Ajayi *et al*., 2018; Ahmed *et al*., 2023). In a seedling drought experiment conducted under very hot and dry conditions, many cowpea seedlings recovered after exposure to 43 days of drought (Hall, 2012; Cui *et al*., 2020).

Phenotyping cowpeas for drought tolerance is especially challenging due to the complexity of the trait, and the lack of effective phenotyping and screening approach (Ravelombola *et al*., 2018). Several researchers have conducted drought screening of cowpea in the field (Alidu, 2018; Batieno *et al.*, 2016; Ishiyaku and Aliyu, 2012; Santos *et al.*, 2020). The field results were shown to be affected by heterogeneity of temperature and water transmission in the soils (Alidu, 2018). Under greenhouse experiments, stem greenness, survival, and recovery are the most reliable traits to distinguish tolerant and susceptible cowpea genotypes (Olubunmi, 2015).

Therefore, phenotyping for drought tolerance at the seedling stage could be a promising alternative when conducted under controlled condition (Hall, 2012). Information on tolerance of cowpea landraces at the seedling growth stage in Northern Nigeria would be substantial to mitigate the effect of climatic changes within the region. Additionally, cowpea cultivars with proven drought tolerance at the seedling stage are limited, and this has prompt cowpea breeders to explore new sources of variation for sustainable improvement programmes at mitigating the increasing threats to cowpea production. The study was conducted to explore the effect of seasonal variation and drought tolerance on seedling growth of cowpea genotypes cultivated in Northern Nigeria. Hence, the effect of seedling drought on cowpea arising from increased temperatures was assessed to mitigate and foster resilience to progressive climatic change.

## MATERIALS AND METHODS

A total of four hundred and twenty-two (422) cowpea accessions were used for the study (Table 1). Three hundred and eight (308) cowpea landraces were collected from local farmers and identified by their local names and characteristics. One hundred and fourteen (114) cowpea lines were obtained from the core collection of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. These cowpea lines comprised of one (1) drought tolerant check (Danila) and one (1) drought susceptible check (TVU-7778). Two separate experiments were conducted at the screen house, Department of Botany, Ahmadu Bello University, Zaria in a wooden box set up. The first experiment was conducted from 2$^{nd}$ November, 2020 to 16$^{th}$ December, 2020 in a daily temperature range of 6 $^{o}$C – 18 $^{o}$C, this was tagged experiment I. Experiment II was conducted from 22$^{nd}$ March, 2021 to 29$^{th}$ April, 2021 in a daily temperature range of 22 $^{o}$C – 36 $^{o}$C. All other growth conditions and set up were maintained for both experiments.

River sand and farm top soil were sieved and mixed thoroughly at a ratio of 3:1. The soil mixture was placed in wooden boxes of 100 x 50 cm dimensions. Each box comprised of 20 entries (genotypes) with five seedlings per entry. The boxes were irrigated and allowed to drain. Seeds were treated with fungicide (Apron star) to prevent soil-borne diseases. Healthy seeds were planted and laid out in a randomized complete block design (RCBD) with two replications. The boxes were irrigated (temperature of irrigation water corresponded to daily temperature) daily until germination (Singh *et al*., 1999; Fatokun *et al*., 2012; Ravelombola *et al*., 2018; Cui *et al*., 2020).

Irrigation was withheld at approximately 14 days after planting when 85 % of the seedlings have at least one trifoliate. Soil temporal moisture content was monitored by random collection at different depths (Olajide and Ilori, 2017; Santos *et al*., 2020).

Data on number of plants per plot, trifoliate number and plant height was collected at 5-day interval. Leaf Senescence was scored visually to determine the senescence due to water deficit stress using a scale of 1 - 5. Stem greenness was recorded when the susceptible genotype was completely dead. Stem greenness was assessed as: Not green (0) or Green (1). Irrigation was resumed when seedlings of drought sensitive check (TVu-7778) reached permanent wilting point. Recovery rate was assessed as the number of plants that fully recovered after a week of irrigation (Ajayi *et al*., 2018). The same methodology was employed in both experiment I and II.

Data obtained were subjected to Analysis of Variance (ANOVA) to ascertain the significance of changing temperatures on cowpea productivity.

Table 1: List of cowpea accessions used in the study, entry number and state of collection

| Accession Name | Entry name | State |
|---|---|---|
| ABU_Vu001-ABUVu_014, ABU_Vu269 | Bosop Gombe, Bosop 2 Gombe, Dan Misra, Iron Beans, Iron Beans 2, Iron Brown Gombe, Jan Wake, Sea, Wake Mai Bakin Kono, Wake Mai Borgo, Wake Mai Borgo Ja, Yebbereru Gombe, Yebbereru 2, Yebbereru Mai Farin Hanci, Aloka Dan Gombe | Gombe |
| ABU_Vu015 - ABUVu_027 | Yar 40, Anannadi, Bosop Taraba, Brown Beans Taraba, Dan Ogoja, Iron Beans_Taraba, Kanannado_Taraba, Ogoja, Silver Taraba, Wake Mai Yaduwa, Warwarbashi, Yar Malaysia, Yebbereru Taraba | Taraba |
| ABU_Vu028 - ABUVu_031, ABU_Vu033, ABU_Vu035, ABU_Vu199, ABU_Vu201 | Kwankwaso Benue, Yar Misra, Tiligali, Nafi, Komcall 1, Oloyin, Belata Benue, Shiswa | Benue |
| ABU_Vu032, ABUVu_034, ABU_Vu145, ABU_Vu148, ABU_Vu151, ABU_Vu167-ABUVu_171, ABU_Vu240, ABU_Vu289, ABU_Vu294 | Gbako 3, Bida 2, Chanchaga 2, Zungeru, Bida1, Kanannado Niger, Maifitila, Kwankwasiya Niger, Jan Wake Niger, Chanchaga 1, Kontagora, Gbako 1 , Gbako 2 | Niger |
| ABU_Vu036 - ABUVu_037, ABU_Vu039-ABU_Vu047, ABU_Vu195-ABU_Vu198, ABU_Vu301 | Hannun Marini_Zamfara, Bahaushe Zamfara, Dan Emir, Dan Dam, Kanana, Dan Zafi, Kanannado Zamfara, Dan Misra Zamfara, Mai Bakar Kowa, Ife Brown Zamfara, Dan Agaji, Iron Beans Zamfara, Oloru, Dan Wari Zamfara, Medial, Dan Misra 2 Zamfara | Zamfara |

**Table 1 Continue**

| | | |
|---|---|---|
| ABU_Vu048-ABU_Vu062 | Bahaushen Wake, Bahaushen Sokoto, Kanannado Sokoto, Kalabas, Sababba Sata, Dan Galankawa, Iron Beans_Small Sokoto, Dan Misira Sokoto, Farin Wake_Sokoto, Iron Beans_Big Sokoto, Kanana Wake, Olowin(Milk), Drum, Olowin (Red), Zafa Sokoto | Sokoto |
| ABU_Vu063 - ABUVu_074, ABU_Vu162-ABUVu_166, ABU_Vu298 | Wake Dan Yagau, Farin Wake_Kebbi, Sa Babba Sata, Kanannado_Kebbi, Milk Sobo, Farin Sobo, Ka Ki Ganin Shono, Jan Sobo, Dan Hausa, BaAre, Kalan Madara, Olanyo, Dan Sokoto, Sa-Babba-Satah, Sobo_Kebbi, Dan Rima, Dan Ilela , Kananando Kebbi 2 | Kebbi |
| ABU_Vu075-ABUVu_084, ABU_Vu182 to ABUVu_187 | Bakin Hantsi, Kanannado Adamawa, Waken Gombe, Jan Wake_Adamawa, Oloto, Geila, Iron Beans Adamawa, Kili Banjaram, Banjaram_Adamawa, Kere-Kere, Jan Bosok, Farin Bosok, Bakin Hanci_Adamawa, Kanannado Adamawa, Mai Madara Adamawa, Silva Adamawa | Adamawa |
| ABU_Vu085-ABUVu_096, ABU_Vu263 - ABU_Vu264 | Ci Kai Shiru Red, Ci Kai Shiru White, Farin Wake_Manya, Farin Wake Qanana, Farin Wake Matsakaita, Honey Beans Bauchi, Kanannado_Bauchi, Red Beans-Big, Red Beans-Medium, Red Beans-Small, Silver_Bauchi, Yabbareru Bauchi, Iron beans- Bauchi, Medium Beans Bauchi | Bauchi |
| ABU_Vu097 to ABUVu_115 | Aloka Borno, Bangara Borno, Borno Yasu, Bornoji, Dinka, Genchein, Gwalam, Iron Beans Borno, Jan Baki, Kanannado Borno, Kolobe, Mai Madara Borno, Oho, Rangem, Warwara Bashi, Banjiram Kanannado, Dimairi, Kiri-Kiri, Sulpha | Borno |
| ABU_Vu116-ABUVu_124, ABU_Vu176 - ABUVu_181, ABU_Vu265-ABU_Vu267 | Honey Beans Jos, Honey Brown Beans, Iron Beans Jos, Medium Beans Plateau, Yabbarere Plateau, Dan Zaria, Mai-Toka, Achi Shiru Fari, Achi Shiru, Bakin Acishiru, Mada (Small), Bikara_Plateau, Bakin Kanannade, Ruwan Kasan Kanannade, Mada (Large), Iron Beans_Big Plateau, Iron Beans_Medium Plateau, Iron Beans_Small Plateau | Plateau |
| ABU_Vu125-ABUVu_140 | Jan Wake Yobe, Yabbereru Yobe, Wake Mai Bargo, Aloka Yobe, Jangau, Banjara Yobe, Iron Beans Yobe, Fari Manyan Kwaya, Dan Umaru, Yambari, Wake Dan Chadi, Karaduwa Fari, Bosho Yobe, Silver Yobe, Karaduwa Yobe, Olotu | Yobe |
| ABU_Vu172, ABU_Vu174-ABU_Vu175, ABU_Vu241-ABU_Vu253, ABU_Vu262-ABU_Vu263 | Shell Bean, Pea Beans Patiskum Medium Beans, Jan Wake Nassarawa, Namu Beans, Yan Barere Nasarawa, Iron Beans Nassarawa, Kwana Arbain, Si Beans, Lafia Beans 1, Lafia Beans 2, Kwankwasiya Nassarawa, Oshiki Ja, Silver Beans Nasarawa, Oshiki Fari, Kanannado Nassarawa, Hot Beans Nasarawa | Nassarawa |
| ABU_Vu173, ABU_Vu200, ABU_Vu268 | Aye Talba, Ewa funfun, Ewa pupa | Kwara |

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**Table 1 Continue**

| | | |
|---|---|---|
| ABU_Vu188 - ABU_Vu194, ABU_Vu270 - ABU_Vu274 , ABU_Vu295 | Jan Wake_Jigawa, Kanannado_Jigawa, Aloka_Jigawa, Dankaka_Jigawa, Yozka 1, Bakolo_Jigawa, Dan Wuri_Jigawa, Dan Kwamaza, Dan Gwambi, Aloka Yabbarere, Kanannado_Jigawa 2, Ja Kanannado, Yozka 2 | Jigawa |
| ABU_Vu202 to ABU_Vu223 ABU_Vu275- ABU_Vu278 ABU_Vu299 - ABU_Vu300, ABU_Vu302- ABU_Vu308 | Dan Malan, Dan Kwari, Dan Masar, Yan Barere_Kano, Iron Beans_Kano, Siver_Kano, Dan Eka, Gama Gari Mai Yado, Dan Wuri_Kano, Kwankwaso, Hannun Marini_Kano, Dan Tsaye, Kanannado Dan Kaka, Dan Kaka_Kano, Dan Ilan, Karaduwa, Dan Arewa, Mai Kasa, Oluka, Dan Ringin, Dan Misra_Kano, Dan Feshi, Bakolo_Kano, Dan Harisu, Komfita, Kyanbas, Dan Eka Kano 2, Big Brown _Kano, Butter Beans_Kano, Pure Pure, Drone, Butter Beans Kanana_Kano, Honey Beans_Kano, Black Beans_Kano, Uloyi_Kano | Kano |
| ABU_Vu143, ABU_Vu144, ABU_Vu146, ABU_Vu147, ABU_Vu149, ABU_Vu150, ABU_Vu152- ABU_Vu161, ABU_Vu224 to ABU_Vu239 | Kenenede Small White, Kenenede Big White, Kenenede Ash, Waken Rumfa, Birinyang, Npak (Small), Kenenede Red, Waken Hausawa, Acishuru_Black Eyed, Mai Glass Red Eyed, Whitish Brown, Large Brown, Benta_Kaduna, Mai Glass Black Eyed, Mai Zabuwa, Acishuru_Red Eyed, Iron Beans_Kaduna, Medium Beans_Kanuna, Kanannado Kaduna, Milk Kaduna, Honey Beans Kaduna, Dan Giwa, Dan Kaya Kaduna, Dan Shika_Kaduna, Dan Misra Kaduna, Dan Muzakkar Kaduna, Bakin Wake Dan Ghana, Jan Wake Kaduna, Wake Mada Brown, Wake Mada White, Wawa Mata, Waken Rumfa Brown | Kaduna |
| ABU_Vu254 to ABU_Vu260 | Kanannado_Abuja, Brown Beans Abuja, Hot Beans Abuja, Honey Beans Abuja, Butter Beans Abuja, Iron Beans_Abuja, Flor-Flor Beans, | Abuja |
| ABU_Vu279- ABU_Vu288 , ABU_Vu290- ABU_Vu293 , ABU_Vu296- ABU_Vu297 | Dan Misrah 2_Katsina, Dan Muzakkar_Katsina, Dan Barari, Farin Wake_Katsina, Bakin Wake, Ndakosode, Honey Brown_Katsina, Olonyi, Butter Beans_Kastsina, Iron Beans_Katsina, Dan Misra Katsina, Dan Shika_Katsina, Zafa_Katsina, Medium Bakin Baki, Sobo_Katsina, Kanan Nado | Katsina |
| ABU_Vu419- ABU_Vu420 | ABU_Vu419, ABU_Vu420 | Kogi |
| ABU_Vu038, ABU_Vu141 - ABUVu_142, ABU_Vu309 - ABU_Vu418, ABU_Vu421- ABU_Vu422 | TVu7778, Tvu 2027, Tvu 17470, Tvu-16921, Tvu-16924, Tvu-16928, Tvu-16929, Tvu-16934, Tvu-16935, Tvu-16936, Tvu-16937, Tvu-16941, Tvu-16942, Tvu-16943, Tvu-16946, Tvu-16947, Tvu-16948, Tvu-16949, Tvu-16950, Tvu-16952, Tvu-16954, Tvu-16955, Tvu-16956, Tvu-16958, Tvu-16961, Tvu-16962, Tvu-16963, Tvu-16964, Tvu-16966, Tvu-16967, Tvu-16968, Tvu-16969, Tvu-16970, Tvu-16971, Tvu-16972, Tvu-16973, Tvu-16974, Tvu-16976, Tvu-16977, Tvu-16978, Tvu-16979, Tvu-16980, Tvu-16982, Tvu-16984, Tvu-16985, Tvu-16987, Tvu-16988, Tvu-16989, Tvu-16990, Tvu-16991, Tvu-16992, Tvu-16994, Tvu-16995, Tvu-16996, Tvu-16997, Tvu-16998, Tvu-16999, Tvu-17000, Tvu-17001, Tvu-17002, Tvu-17003, Tvu-17004, Tvu-17005, Tvu-17006, Tvu-17007, Tvu-17008, Tvu-17009, Tvu-17010, Tvu-17011, Tvu-17012, Tvu-17013, Tvu-17014, Tvu-17015, Tvu-17016, Tvu-17017, Tvu-17018, Tvu-17019, Tvu-17020, Tvu-17022, Tvu-17023, Tvu-17024, Tvu-17025, Tvu-17026, Tvu-17027, Tvu-17028, Tvu-17029, Tvu-17030, Tvu-17031, Tvu-17032, Tvu-17034, Tvu-17035, Tvu-17037, Tvu-17038, Tvu-17039, Tvu-17040, Tvu-17041, Tvu-17042, Tvu-17043, Tvu-17044, Tvu-17045, Tvu-17046, Tvu-17047, Tvu-17048, Tvu-17049, Tvu-17051, Tvu-17360, Tvu-17461, Tvu-17462, Tvu-17464, Ife Brown, Danila, IT84S-2246-4, Tvu-14676, Tvu-16927, Tvu-16993 | IITA, Ibadan |

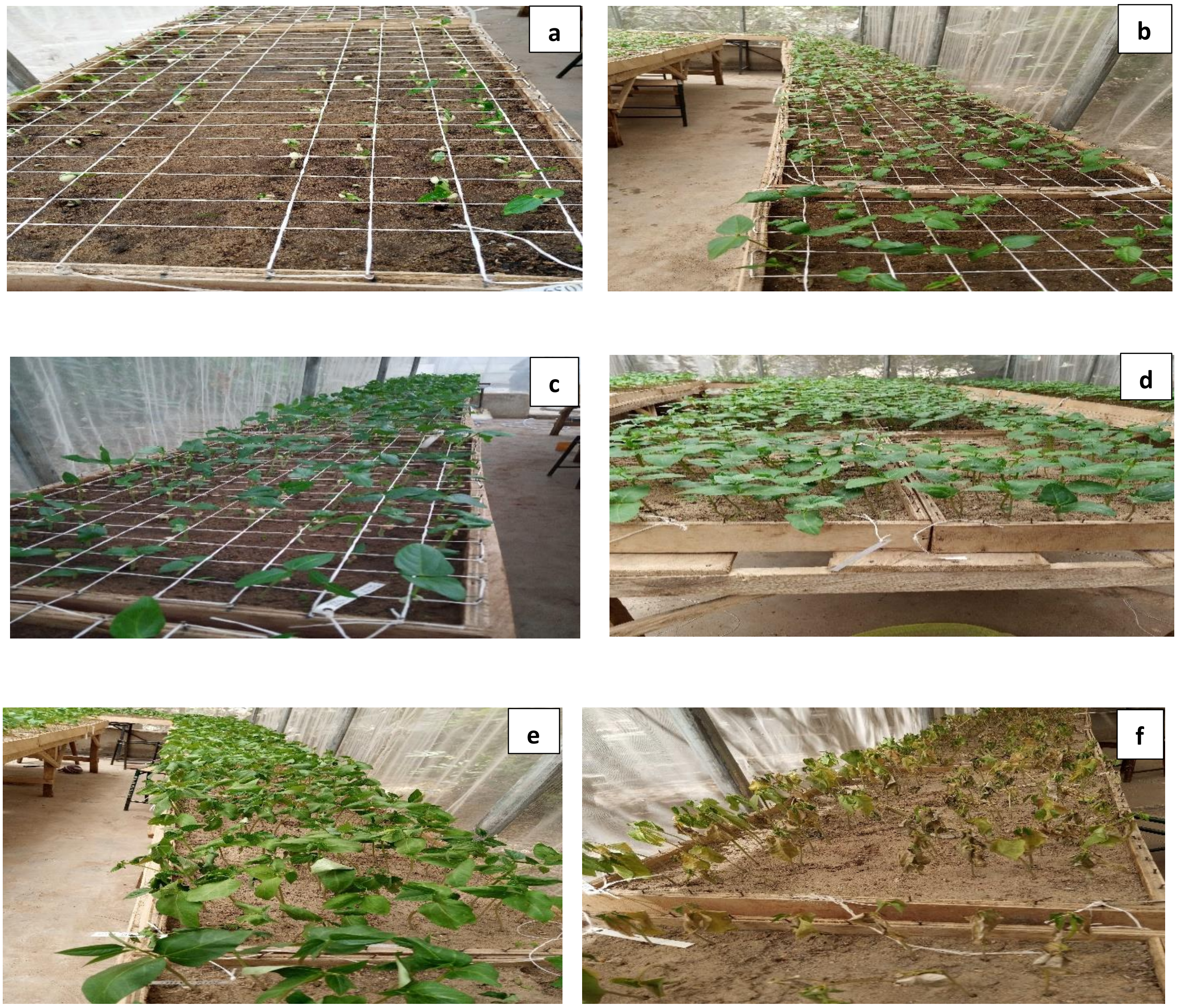


**Figure: 1a-f**: Seedlings at different days after sowing (DAS) (5, 10, 15, 20, 25 and 30 DAS) along the seedling growth stages from germination to leaf senescence

## RESULTS

Analysis of variance on the number of plants (PN), plant height (PH), number of trifoliate (TN), leaf senescence (LS), stem greenness (SG) and percentage recovery (RR) revealed significant variations ($P < 0.05$) in both experiments (Table 2). The corresponding mean square values for the number of plants, trifoliate and stem greenness observed in experiment II (474.86, 18.21, and 7406.52 respectively) were significantly higher than values recorded in experiment I. In contrast, respective mean square values for plant height, leaf senescence and percentage recovery (7657.34, 497.91, and 628.84) in experiment I were greater than same parameters (7587.46, 434.70 and 170.51) observed in experiment II (Table 2).

Table 2: Mean Square for the traits of cowpea at seedlings drought during two temperature regimes

| | Mean Square | |
|---|---|---|
| Trait | EI (6 °C – 18 °C) | EII (22 °C – 36 °C) |
| PN | 147.94* | 474.86* |
| PH | 7657.34* | 7587.46* |
| TN | 17.93* | 18.21* |
| LS | 497.91* | 434.70* |
| SG | 5734.56* | 7406.52* |
| RR | 628.84* | 170.51* |

**Key:** EI-Experiment I, EII- Experiment II, PN- Number of plants, PH- Plant height, TN-Number of trifoliate, LS- Leaf senescence, SG- Stem greenness, RR- Percentage recovery. * Significant at $p < 0.05$

The correlations of morphological traits in response to seedling drought in experiments I and II are presented in table 3. Significant correlations ($p \leq 0.05$) in morphological traits were obtained. Correlation coefficients (r) among plant height, number of trifoliate and number of plants were 0.520, 0.403 and 0.495 in experiment I. The r values for the same traits were 0.484, 0.597 and 0.544 in experiment II. Stem greenness showed no association with leaf senescence at cold temperatures. Recovery rate at cold temperatures was better associated with stem greenness than at hot temperatures.

The percentage of recovery of top performing genotypes in experiments I and II are presented in Figure 2a - b. Percentage recovery was differential and ranged 25.0 % to 100.0 % in both experiments. However, the number of genotypes with high percentage recovery was obtained with experiment II. ABU_Vu213, ABU_Vu221 and ABU_Vu201 landraces showed 100.0% recovery in experiment I. Landraces ABU_Vu150, ABU_Vu239 and ABU_Vu279 showed 100.0% recovery in experiment II. ABU_Vu26, ABU_Vu150 and ABU_Vu256 showed recovery in both experiments.

Table 3: Correlationship between morphological traits in cowpea seedling under drought condition at two temperature regimes

| Trait | PN | PH | TN | LS | SG | RR |
|---|---|---|---|---|---|---|
| PN | 1.000 | 0.520** | 0.403** | 0.611** | 0.316** | 0.050 |
| PH | 0.484** | 1.000 | 0.495** | 0.457** | 0.302** | 0.071* |
| TN | 0.597** | 0.544** | 1.000 | 0.489** | 0.468** | 0.102* |
| LS | 0.403** | 0.257** | 0.337** | 1.000 | 0.282** | -0.007* |
| SG | 0.134** | 0.062 | 0.101** | 0.009 | 1.000 | 0.161** |
| RR | 0.029 | 0.031 | 0.052 | -0.028** | 0.186** | 1.000 |

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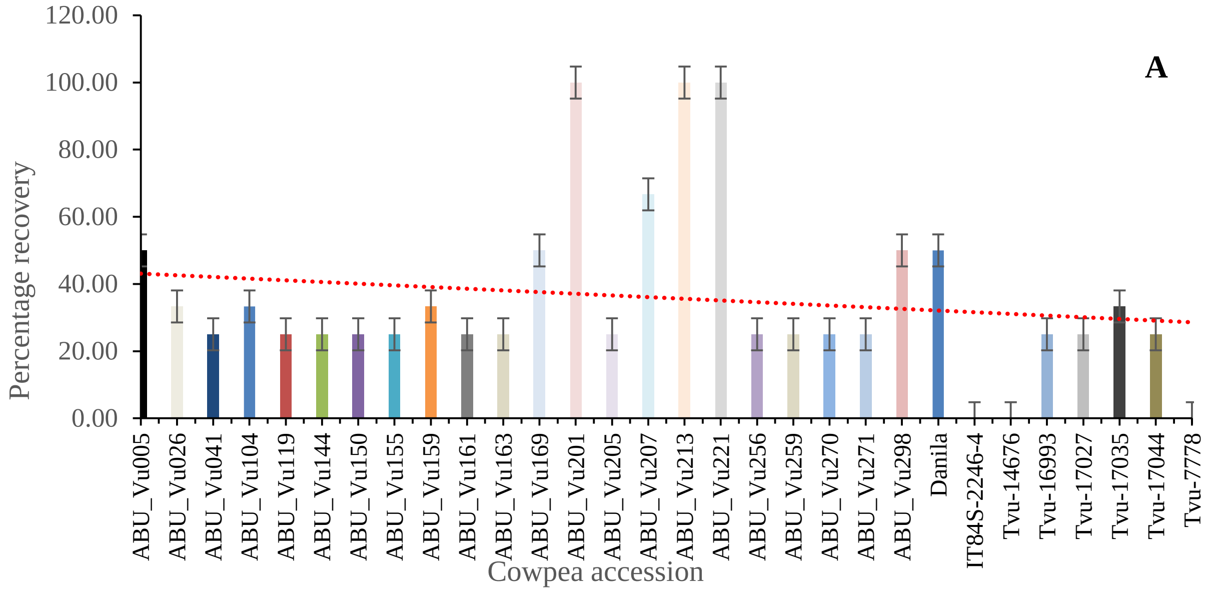


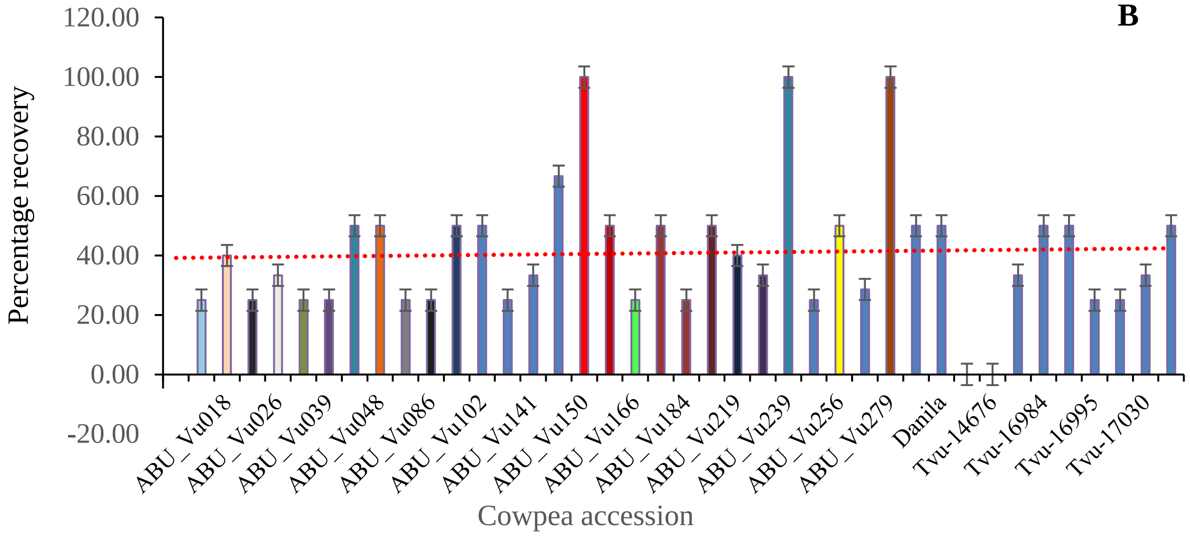


Experiment I (in red fonts) Experiment II (in black fonts)

**Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level

Key: PN- Number of plants, PH- Plant height, TN- Number of trifoliate, LS- Leaf senescence, SG- Stem greenness, RR- Percentage recovery

**Figure 2a-b:** Percentage recovery of top performing cowpea genotypes subjected to seedling drought at 6 - 18 °C (A) and 22 - 36 °C (B)

## DISCUSSION

Due to climate change, temperatures are rising with time. Cowpea is predominantly cultivated in arid and semiarid regions in Nigeria. Low productivity still lingers significantly which is attributable to a host of abiotic and biotic stressors. A large variation in the traits evaluated for seedling drought was significantly influenced by temperature. Majority (91 %) of the cowpea genotypes in the current study were susceptible to drought stress and this is attributable to inability of the susceptible plants to maintain stem greenness (loss of photosynthetic ability) thus leading to senescence and plant death. Photosynthetic incapacitated plants were unable to recover at the resumption of irrigation. Similar effect of drought has been reported by several studies (Pungulani *et al*., 2013; Qin *et al*., 2018; Ravelombola *et al*., 2018; Yahaya *et al*. (2019) and Alidu (2018) reported that variation in cowpea response to drought depended on genotype, drought intensity and the growth stage.

Plant greenness score and recovery rate have been previously shown to be accurate parameters for assessing drought tolerance at seedling stage in cowpea (Ravelombola *et al*., 2018). The present study is corroborated by the findings of Santos *et al*. (2020) who reported lower value of stem greenness in cowpea genotypes subjected to drought compared to the control. Stem greenness is an important indicator of drought tolerance in cowpea genotypes at a seedling stage. Muchero et al. (2008) evaluated the drought response of cowpea at the seedling stage and reported that drought-related traits such as stem greenness are used to identify contrasting cowpea genotypes.

Positive correlations among morphological and recovery parameters suggests that seedlings with more trifoliate number during drought stress will recover faster through regrowth and stem greenness. Likewise, the taller the plant, the greater the chances of survival and recovery. The findings in the current study are in line with the report of Ajayi et al. (2018) who reported strong positive correlation of plant height, stem greenness and recovery. According to them, these are among the best traits for use in the study of drought tolerance in seedlings of cowpea. The negative correlation between leaf senescence and recovery experienced in both experiments of the current study was also supported by Ajayi et al. (2018).

There are unbalanced phenotypic responses of cowpea varieties to different temperature regimes. Despite the heat-loving characteristics of cowpea, some varieties succumbed to drought with increasing temperature. According to Barros et al. (2023), high temperatures may have a direct impact on physiological processes in cowpea. Angelotti et al. (2020), in their study on cowpea using three temperature regimes, opined that temperature (18 $^{o}$C –34 $^{o}$C) influenced optimum agro-morphological traits and concluded that it is suitable for cowpea production. At higher temperatures (> 34 $^{o}$C), there was an observed decrease in photosynthetic activity and an increase in leaf temperature; these in turn affected the stem greenness and favoured rapid leaf senescence (Barros *et al*., 2023). Similarly, in this study, due to the rapid loss in stem greenness and subsequent senescence, only a few cowpea accessions (9.0 %) recovered after the drought imposition at high temperatures. At colder temperatures, the genotypes showed commendable resilience to recovery rate (Hall, 2004; Barros *et al*., 2023).

## CONCLUSIONS AND RECOMMENDATION

Temperature has detrimental effect on drought stressed plants. At colder temperatures, drought stressed cowpea showed good resilience to drought recovery at seedling stage.

However, drought is more detrimental to cowpea productivity at cooler temperatures as it affects emergence, vigour, and photosynthesis (only 9.0 % of cowpea accessions recovered after drought). ABU_Vu213, ABU_Vu221 and ABU_Vu201 (showed 100.0% recovery despite drought imposition at cooler temperatures) are superior landraces that could ameliorate drought at cold temperatures. ABU_Vu041, ABU_Vu119, ABU_Vu144, ABU_Vu150, ABU_Vu155, ABU_Vu161, ABU_Vu163, ABU_Vu205, ABU_Vu256, ABU_Vu259, ABU_Vu270 and ABU_Vu271 are inferior landraces that showed poor performance at colder temperatures. Drought tolerant landraces under both temperature regimes could be harnessed for improved productivity, breeding and development of climate-resilient cowpea varieties.

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