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Morphological and Physiological Performance of Indian Soybean [*Glycine max* (L.) Merrill] Genotypes in Respect to Drought

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ABSTRACT

Background: Soybean is a key crop that grants an imperative supply of oils and proteins to humans and animals; however, its productivity spectacularly diminished owing to the occurrence of drought stress.

Methods: The present investigation was executed during *Kharif* 2018-2019 to recognize drought tolerant genotypes on the basis of an array of morpho-physiological traits. Morpho-physiological analysis among 53 genotypes divulged the existence of drought tolerance capability in studied genotypes.

Result: On the basis of current findings, it can be concluded that drought stress retards the growth and metabolic activity of soybean genotypes. These parameters showed considerable amount of variability under drought stress at different growth stages in soybean. Among 53 soybean genotypes, four genotypes *viz.,* JS97-52, AMS 2014-1, RVS-14 and NRC-147 was found to be drought tolerant.

Key words: Climate change, Diversity, Drought, Genotypes, Morpho-physiological traits.

INTRODUCTION

Drought is a significant destructive issue that influences each and every phases of plant growth and development. Soybean is a species susceptible to a number of abiotic factors (Van Heerden and Krüger, 2000; Mishra *et al.,* 2021), in comparison to other legumes, for instance *Vigna unguiculata* and *Phaseolus vulgaris* (Roy-Macauley *et al.,* 1992; Silveira *et al.* 2003; Sepanlo *et al.* 2014*;* Kachare *et al.* 2019), in addition to others crop species as cotton, sorghum (Younis *et al.* 2000) and chickpea (Talebi *et al.,* 2013; Gupta *et al.,* 2021; Shahu *et al*., 2020). Drought stress, which habitually transpires at pod filling periods, found momentous yield hammerings, up to 40% in a year and it depreciates the seed superiority of soybean (Jaleel *et al.,* 2009; Manavalan *et al.,* 2009). Per annum, about 40% diminution happens in soybean yield owing to drought (Specht *et al.,* 1999). It is a striking restrictive aspect to inhibit productivity and plant growth as a result of diminished water amalgamation and nutrient uptake (Moradi *et al.,* 2015). This curb for water conveys in agriculture is anticipated to augment in the future because of expansion of populace and economical segments excluding agriculture (Araus, 2004). As the living of millions of little and subsidiary farmers depend on this crop and seeming at its substance in country's oil cutback, there is an urgent need to improve soybean productivity (Tiwari and Tripathi, 2004; Tripathi and Tiwari, 2005; Upadhyay *et al*., 2020), which can be attained principally by improving the tolerance against drought.

Drought tolerance in plants is an exceedingly multifaceted incident that engages multiple genetic, morphological, physiological, biochemical and molecular mechanisms. The degree of plant drought tolerance oscillates not only among diverse species (Save *et al.,* 1995; Serraj *et al*., 2004; Talebi *et al.,* 2013) but also amongst different varieties of the similar species (Sepanlo *et al.,* 2014). Hence, plants undergo an array of alterations at the molecular level leading to its morpho-physiological and biochemical adjustment in reply to drought. Drought stress escorts to interruption in stomatal mechanism, gas exchange, metabolism activities, cell structure, ultimately enzyme catalyzed reactions and expression of diverse genes (Paul *et al.,* 2011). Genetic improvement of stress tolerance in crop plants necessitates recognition of pertinent morpho-physiological parameters to be employed as selection criteria (Kumar *et al.,* 2014; Sepanlo *et al.,* 2014; Kachre *et al.,* 2019; Mishra *et al.,* 2022; Upadhyay *et al.,* 2020; 2023).

Drought adjustment is decided by way of diverse morpho-physiological attributes in crop plants (Seplano *et al.,* 2014; Kachare *et al.,* 2019). Amongst an array of morpho-

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physiological traits, root-shoot length, shoot-root biomass, vigor index, relative water content, turgidity and stomatal conductance play a vital function in influencing the intensity of drought adaptation (Hossain *et al.*, 2015; Kachare *et al.,* 2019; Sahu *et al.,* 2022). To survive under unfavorable growth conditions, plants develop unique defense mechanisms and processes for acclimation that increases their tolerance to detrimental conditions (Xu *et al.,* 2008). As soybean is cultivated exceeding an extensive choice of circumstances, but information related to morphological and physiological changes in the plant organs under drought stress is missing. The intend of the current work was to scan the consequences of drought on numerous morphological and physiological traits of soybean.

MATERIALS AND METHODS

Fifty-three soybean genotypes (Table 1) with diverge feedbacks against drought *viz*: susceptible and tolerant were acquired from College of Agriculture, JNKVV, Jabalpur, RAK, College of Agriculture, Sehore and Zonal Agricultural Research Station, Morena, RVSKVV, Gwalior, M.P., India. The field trial was accomplished at the investigational plot and the laboratory work at the Biochemical Analysis Laboratory, Department of Plant Molecular Biology and Biotechnology, College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwavidyalaya, Gwalior, Madhya Pradesh, India in the session of *Kharif* 2018-19. The Gwalior is located at 22°43′ N Latitude and 76°54′ E longitudes and altitude 618 m above the sea level. This fragment has subtropical, semi-arid climate with hot and dry summers and cold winters with irregular showers. The usual rainfall was about 312.0 mm in July, 190.6 mm in August, 166.4 mm in September and 0.0 mm in the month of October correspondingly. Crop was shown on dated 27th July 2018. Flanked by 60th to 70th days of crop growth period neither rain has been amused naturally nor irrigation has provided physically. The trial was performed in randomized block design in three rows with two replications and row to row detachment was kept 30 cm. Fertilizer was applied in the ratio of 20 N: 60 P_2O_5: 20 K_2O:20S kg ha^{-1}. Data were documented subsequent to 70 days of sowing from five randomly chosen plants from every line and replication for recording various morpho-physiological traits. Plant height, root /shoot ratio, canopy temperature, fresh weight (FW), dry weight (DW), turgid weight (TW), relative water content (RWC) and saturation water deficit (SWD) were calculated according to the methods adopted by Kachare (2017).

Table 1: List of soybean genotypes with their parentage.

S. no.	Genotypes	Source/Pedigree	S. no.	Genotypes	Source/Pedigree
1.	JS 20-29	JS 97-52 × JS 95-56	28.	RSC-10-52	NRC 37 × JS335
2.	JS 20-69	JS 97-52 × SL 710	29.	SL -1123	Selection from AGS751
3.	JS 335	JS 78-77 × JS 71-05	30.	SL-1068	SL755 × SL525
4.	JS 20-98	JS 97-52 × JS SL710	31.	AGS 111	Germplasm accession
5.	JS 20-94	JS 97-52 × JS 20-02	32.	EC457286	Germplasm accession
6.	JS 93-05	Selection from PS 73-22	33.	MACS725	JS93-05 × MAUS71
7.	JS 20-116	JS 97-52 × JSM 120 A	34.	SP 37	Not known selection
8.	JS 95-60	Selection from PS 73-22	35.	NRC -125	EC54688 × PS1044
9.	JS 97-52	PK 327 × L 129	36.	NRC-132	JS97-52 × PI086023
10.	JS 20-84	JS 98-63 × PK 768	37.	NRC-134	NRC7 × AGS191
11.	JS 20-34	JS 98-63 × PK 768	38.	NRC SL-1	JS335 × SL525
12.	JS 20-71	JS 97-52 × JS 90-5-12-1	39.	PS 1092	PS1042 × MACS 450
13.	RVS 2007-6	JS 20-10 × MAUS162	40.	PS 1613	PS1225 × PS1042
14.	RVS 2011-35	JS 335 × PK 1042	41.	AMS 2014-1	AMS99-33 × H6P5
15.	RVS 2001-4	JS 93-01 × EC 390981	42.	KDS 992	JS93-05 × EC241780
16.	RVS -14	JS 93-05 × EC 390981	43.	VLS -94	VL Soya59 × VS2005-1
17.	RVS -24	J.P 120 × JS 335	44.	SKF-SPS-11	Not known selection
18.	RVS -18	JSM110 × JSM66	45.	RVS 76	MAUS-162 × JSM-66
19.	NRC- 76	NRC-37 × L-27	46.	NRC127	JS97-52 × PI542044
20.	NRC -86	RKS15 × EC481309	47.	KDS980	JS93-05 × AMS1
21.	NRC- 130	EC390977 × EC538828	48.	G-29	Germplasm
22.	NRC -131	EC390977 × EC538828	49.	RSC-10-70	JS335 × Bragg
23.	NRC -147	Germplasm accessions C210	50.	RSC-10-71	Bragg × JS335
24.	AMSMBC -18	Mutant of Bragg	51.	NRC-2	Induced mutant of Bragg
25.	AMS-100-39	Mutant of JS93-05	52.	MACS-15-20	NRC37 × Mohetta
26.	MACS - 1520	EC241780 × MACS330	53.	MACS-58	JS2 × Improve pelican
27.	MACSNRC-1575	PI542044 × JS9305			

RESULTS AND DISCUSSION

Drought stress persuades an assortment of morpho-physiological alterations in plants in order that plants are competent to widen tolerance mechanisms. Drought tolerance is the result of copious morphological, anatomical and physiological traits which interact with continuance of growth and developmental processes. Relative competence for drought tolerance of soybean genotypes may be judged by estimating various morpho-physiological parameters such as plant height, root length, shoot length, root / shoot ratio, canopy temperature, fresh weight, dry weight, turgid weight, relative water content and saturation water deficit.

The analysis of variance presented in Table 2 evidently designated existence of significant sum of dissimilarities in performances among 53 soybean genotypes for diverse morpho-physiological attributes. Plant height varied in range of 44.37 cm to 136.02 cm with maximum in genotype NRC-76 (136.02 cm). A next group of six genotypes having height more than 100 cm including NRC-147(130.97 cm), NRC-131(114.53 cm), NRC-127(111.81 cm), JS20-69 (110.75 cm), RVS-14(106.63 cm) and JS 20-116 (101.46 cm). Whereas genotype VLS -94 was found to be smallest one (44.37 cm). In current investigation it was evident that genotype(s) with short stature showed more tolerance against drought as compared to taller one.

A root organization with longer root length is helpful in pull out water from the soil. Therefore, early and swift elongation of the root is an imperative signal of drought tolerance (El-Siddig *et al.,* 2013). Significant genotypic differences were also examined for root length and was documented in range of 8.82 cm to 38.91 cm with highest in genotype NRC127 (38.91 cm) pursued by NRC-132 (37.98 cm). The next group of two genotypes was NRC-125 (29.83cm) and NRC-134 (27.43cm). The lowest count was 8.82cm for the genotype RVS 2011-35 trailed by two genotypes AMS-100-39 (9.36 cm) and JS 20-34 (9.91 cm). In current investigation, a few genotypes exhibited significantly longer root as compared to others. This surveillance indicated that root elongation helps plants to attain water during drought for better adaptability and acclimatization to avoid water scarcity. Similar verdicts were also reported by Oya (2004) and Kachare (2017) who also documented higher root length association with drought stress in soybean.

Shoot length varied between 28.50 cm to 112.14 cm with utmost in genotype NRC- 76 (112.14 cm) intimately chased by two genotypes namely: NRC-147 (110.72 cm) and NRC-131(101.65 cm). The lowest count was 28.50 cm for the genotype PS1613 tracked by two genotypes VLS -94 (30.14 cm) and NRC SL-1 (35.11 cm). Drought stress adversely affects the shoot growth and increased root development. Throughout the present research, a strong negative correlation between shoot length and drought stress evidently indicated that increase in root length suppressed shoot length. Thu *et al*. (2014) and Kachare (2017) also monitored higher shoot length under control condition with significant differences as compared to water restricted conditions in soybean. The reason behind this seems to be disturbance in the physiological processes originated by the increased in osmotic stress which affects metabolism and eventually reduces plant expansion (Batool *et al.,* 2014).

In addition to the root and shoot length, root/shoot ratio participates a deciding role in selecting the soybean genotypes for drought tolerance as earlier it has been reported that drought tolerant genotypes exhibit balanced root and shoot growth (El-Siddig *et al.,* 2013; Kachare, 2017). Root/shoot ratio varied in range of 0.117359 to 0.777663 with greatest in genotype NRC127 (0.777663) intimately tracked by a group of three genotypes *viz*: JS 97-52 (0.641598), NRC SL-1 (0.627297) and NRC-132 (0.61301). The lowest value was 0.117359 for the genotype AMS-100-39 trailed by two genotypes *viz*., MACS-1520 (0.159366) and RSC-10-52 (0.14612). Therefore, it is concluded that genotypes with increased R/S ratio may be drought tolerant genotypes. Makbul *et al*. (2011) also observed that root to shoot ratio increases with drought stress because water stress suppresses the shoot growth of the soybean genotypes rather than root growth. Osmotic potential disturbed the equilibrium of root and shoot growth as root length increased and shoot length declined.

On the basis of cluster analysis of morpho-physiological traits (plant height, shoot and root length and root/shoot ratio) dendrogram, soybean genotypes outlined two clusters. Major cluster consisted 48 genotypes while minor cluster had only five genotypes, namely: NRC-78, NRC-147, NRC-131, JS20-69 and RVS-14. The major cluster further divided into two groups. First group consisted 23 soybean genotypes, however, second group had 25 genotypes. First group was again splinted into two sub groups major and minor. Major sub group hold twenty-one genotypes, *viz*., NRC-134, JS97-52, AGS-111, KDS-992, SL-1, MACS-58, RVS 2011-3, SKF-SPS-1, JS93-05, MACS-15-20, JS95-60, EC-457286, AMS 2014-1, JS20-84, JS20-34, SL-11-23, PS-10-92, KDS-980, NRC-2, G-29 and PS-1613, while minor sub group had genotypes VLS-94 and JS20-71. Second group consisted 25 genotypes and it was further divided into two sub groups one major and one minor. Major group contained 21 genotypes, *i.e*., JS20-71, RSC-10-71, JS20-94, NRC-130, NRC-86, RSC-10-70, JS-335, JS20-98, MACS-725, SL-1068, RVS-18, MACSNRC-1, JS20-116, RVS2007-8, RVS2001-4, RVS-24, AM-SM-BC-1, JS20-29, AMS100-39, MACS-162 and RSC-10-52 whereas minor sub group included four genotypes including NRC-125, RVS-76, NRC-132 and NRC-127 (Fig 1).

Evett *et al*. (2000) noted that the canopy temperature measurement with infrared thermometers has been an effective tool for semi-arid and arid conditions. The soybean temperature thresholds were based on the optimum canopy temperatures for peak photosynthetic enzyme activity, which were found to be 27°C (Fig 2). In present research, canopy temperature was ranged from 32.30°C (SL-1068) to 36.0°C (RVS2011-35) with greatest of genotype RVS 2011-35

Table 2: Mean performance of different morpho-physiological traits of soybean genotypes.

Genotypes	Root types and morphology	Plant height	Root length	Shoot length	Root/ shoot ratio	Canopy temperature (°C)	Turgid weight (g)	Fresh weight (g)	Dry weight (g)	RWC (%)	SWD (%)
JS 20-29	Branched tap root	93.71	14.16	79.55	0.17	33.60	144.62	124.15	112.33	36.61	63.38
JS 20-69	Highly branched tap root and lateral root	110.75	19.95	90.80	0.21	33.55	118.30	101.15	76.33	59.15	40.84
JS 335	Highly branched tap root and lateral root	83.44	19.29	64.15	0.30	33.50	91.00	75.50	60.66	48.83	51.16
JS 20-98	Highly branched tap root and lateral root	79.98	16.72	63.26	0.26	33.25	78.50	71.00	60.68	57.96	42.03
JS 20-94	Highly branched tap root and lateral root	87.48	17.28	70.20	0.24	33.05	107.00	96.15	79.66	60.38	39.61
JS 93-05	Highly branched tap root and lateral root	69.86	16.13	53.73	0.30	33.25	126.15	111.31	87.16	61.99	38.00
JS 20-116	Highly branched tap root and lateral root	101.46	20.15	81.31	0.24	33.25	92.165	79.00	67.00	47.73	52.26
JS 95-60	Highly branched tap root and lateral root	71.35	16.98	54.37	0.31	34.15	113.00	99.00	75.165	63.04	36.95
JS 97-52	Highly branched tap root and lateral root	64.33	25.14	39.19	0.64	35.15	122.65	114.00	95.00	68.72	31.27
JS 20-84	Highly branched tap root and lateral root	63.18	10.96	52.22	0.20	33.20	62.80	56.80	49.83	53.72	46.27
JS 20-34	Highly branched tap root and lateral root	63.93	9.91	54.02	0.18	33.65	60.30	48.08	45.16	19.47	80.52
JS 20-71	Highly branched tap root and lateral root	80.56	22.96	57.76	0.39	33.40	127.30	78.25	65.00	21.27	78.72
RVS 2007-6	Highly branched tap root and lateral root	97.78	14.26	83.52	0.17	35.25	134.00	108.15	97.83	28.56	71.43
RVS 2011-35	Highly branched tap root and lateral root	70.46	8.82	61.64	0.14	36.60	128.30	97.65	85.00	29.22	70.77
RVS 2001-4	Highly branched tap root and lateral root	96.03	15.93	80.10	0.19	35.10	154.15	122.50	113.16	22.74	77.25
RVS -14	Highly branched tap root and lateral root	106.63	19.23	87.40	0.22	34.35	112.65	88.30	69.83	43.13	56.86
RVS -24	Branched tap root and lateral root	96.81	18.26	78.55	0.23	35.40	100.85	81.15	46.00	64.08	35.91
RVS -18	Branched tap root and lateral root	78.85	11.95	66.90	0.17	34.80	71.15	59.00	43.16	56.58	43.41
NRC- 76	Branched tap root and lateral root	136.02	23.88	112.14	0.21	33.20	105.15	77.00	66.00	28.09	71.90
NRC -86	Highly branched tap root and lateral root	85.70	17.40	68.30	0.25	33.45	229.00	194.66	178.00	32.67	67.32
NRC- 130	Highly branched tap root and lateral root	87.44	17.05	70.39	0.24	33.30	142.15	113.66	99.30	33.50	66.49
NRC -131	Highly branched tap root and lateral root	114.53	12.88	101.65	0.12	33.45	177.015	147.50	134.16	31.10	68.89
NRC -147	Branched tap root and lateral root	130.97	20.25	110.72	0.18	34.80	82.25	65.30	34.16	64.77	35.22
AMSMBC -18	Branched tap root and lateral root	93.08	13.44	79.64	0.16	32.85	34.15	29.30	26.50	36.55	63.44
AMS-100-39	Branched tap root and lateral root	89.12	9.36	79.76	0.11	34.05	165.50	152.50	130.33	63.01	36.98
MACS – 1520	Branched tap root and lateral root	88.34	12.14	76.20	0.15	33.30	133.65	122.80	109.33	55.50	44.49
MACSNRC-1575	Branched tap root and lateral root	80.44	14.73	65.71	0.22	34.05	77.75	63.80	56.00	35.85	64.14
RSC-10-52	Branched tap root and lateral root	89.00	11.35	77.65	0.14	32.45	131.40	115.80	92.16	60.24	39.75
SL -1123	Branched tap root and lateral root	60.77	13.51	47.26	0.28	33.25	123.80	114.15	104.15	50.90	49.09
SL-1068	Branched tap root and lateral root	79.93	18.08	61.85	0.29	32.30	121.30	110.15	95.30	57.17	42.82
AGS 111	Branched tap root and lateral root	63.82	21.95	41.87	0.52	32.40	151.16	134.65	123.12	41.11	58.88
EC457286	Branched tap root and lateral root	67.86	13.90	53.96	0.25	33.50	139.15	108.80	91.85	35.84	64.15
MACS725	Branched tap root and lateral root	81.01	16.91	64.10	0.26	33.45	112.35	104.80	95.80	54.42	45.57
SP 37	Branched tap root and lateral root	67.02	21.71	45.31	0.47	33.75	121.15	105.40	92.50	45.07	54.92
NRC -125	Branched tap root and lateral root	94.03	29.83	64.20	0.46	33.55	140.15	127.65	120.99	34.51	65.48
NRC-132	Branched tap root and lateral root	99.94	37.98	61.96	0.61	33.45	138.25	98.00	82.00	28.44	71.55

Table 2: Continue...

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NRC-134	Highly branched tap root and lateral root	75.73	27.43	48.30	0.56	33.95	92.25	77.94	62.75	51.49	48.50
NRC SL-1	Tap root	57.10	21.99	35.11	0.62	33.80	67.00	52.25	41.00	43.26	56.73
PS 1092	Branched tap root and lateral root	64.68	15.71	48.97	0.32	32.65	103.30	53.41	43.15	17.06	82.93
PS 1613	Highly branched tap root and lateral root	39.70	11.20	28.50	0.39	33.25	133.10	126.50	114.3	64.88	35.11
AMS 2014-1	Tap root	65.63	13.45	52.18	0.25	32.75	108.05	103.65	95.15	65.86	34.13
KDS 992	Branched tap root and lateral root	60.58	19.96	40.62	0.49	33.00	80.415	57.00	38.08	43.92	56.07
VLS -94	Tap root	44.37	14.23	30.14	0.47	33.40	113.30	88.00	71.00	40.19	59.80
SKF-SPS -11	Branched tap root and lateral root	69.81	12.25	57.56	0.21	33.40	86.00	76.50	65.30	54.06	45.93
RVS 76	Branched tap root and lateral root	95.04	24.20	70.84	0.34	34.25	70.00	60.00	48.15	54.23	45.76
NRC127	Highly branched tap root and lateral root	111.81	38.91	72.90	0.77	32.95	114.00	93.35	73.30	49.26	50.73
KDS980	Branched tap root and lateral root	63.40	15.45	47.95	0.32	32.95	62.30	56.44	47.30	60.96	39.03
G-29	Highly branched tap root and lateral root	64.10	14.00	50.10	0.27	33.50	135.41	97.25	78.95	32.37	67.62
RSC-10-70	Tap root	87.26	18.51	68.75	0.26	32.60	82.00	70.30	52.50	60.31	39.68
RSC-10-71	Tap root	77.52	19.81	57.71	0.34	32.70	98.50	83.41	63.65	56.71	43.28
NRC-2	Tap root	63.05	15.12	47.93	0.31	32.80	97.00	49.50	24.30	34.65	65.34
MACS-15-20	Branched tap root and lateral root	68.59	15.85	52.74	0.30	32.65	89.00	69.50	57.50	38.05	61.94
MACS-58	Branched tap root and lateral root	56.92	14.95	41.97	0.35	32.75	52.30	42.25	27.07	60.15	39.84
SE (m)		0.483	0.386	0.628	0.034	-	-	0.521	0.591	0.297	0.759
$CD_{0.05}$		1.372	1.097	1.784	0.098	-	-	1.481	1.678	0.844	2.156

(36°C) intimately pursued by a group of four genotypes *viz*: RVS-24 (35.40°C), RVS 2007-6 (35.25°C), JS 97-52 (35.15°C) and RVS 2001-4 (35.10). While the lowest was recorded for the genotype SL-1068 (32.30°C).

Water saturation deficit, relative water content (RWC) and leaf water loss are the chief physiological criteria that maneuver plant water relations and employed to appraise drought tolerance in plants. Fresh weight of soybean genotypes ranged from 29.30 g to 194.66 g with maximum in genotype NRC-86 (194.66 g) chased by genotypes*:* AMS-100-39 (152.50 g) and NRC-131 (147.50 g), whereas the lowest was evidenced for the genotype AMSMBC-18 (29.30 g). Turgid weight was documented between 34.15 g to 229.00 g with highest for genotype NRC-86 (229.00g) tracked by a group of four genotypes*: viz* NRC-131 (177.015 g), AMS-100-39 (165.50 g), RVS 2001-4 (154.15 g) and AGS 111(151.16 g), while the lowest was detected for the genotype AMSMBC -18 (34.15 g). Dry weight varied in range of 24.30 g to 178.00 g with utmost for the genotype NRC-86 (178.00 g) chased by genotypes: NRC -131 (134.16 g) and AMS-100-39 (130.33 g), however, minimum in the genotype NRC-2 (24.30 g) tracked by genotypes: AMSMBC-18 (26.50 g) and MACS-58(27.07 g). It was observed that water deficit adversely affects plant growth and indicate more changes in dry weight of soybean. As the stomata close in response to low water supply, there is low CO_2 fixation. Apart from reducing cell division and enlargement, water stress is reported to be restrictive to almost all aspects of cellular metabolism. The result in decrease in dry matter production and yield is evident in this study which is accordance to study of Kachare (2017). Sharifa *et al*. (2015) also documented decreased fresh weights with drought stress in soybean genotypes. In many other studies, osmotic stress also caused a significant decrease in fresh weight of soybean genotypes (Hamayun *et al.,* 2010; Sepanlo *et al.,* 2014; Kachare, 2017).

RWC is considered as a prominent physiological parameter to predict tolerance against drought stress. Drought stress causes water loss within the plant and results in relative water content (RWC) reduction. This parameter is one of the most steadfast and extensively used indicator for defining both the sensitivity and the tolerance to water deficit in plants (Rampino *et al.,* 2012). Computation of RWC facilitates in the estimation of the metabolic activity in leaf tissues which is then considered as an integrated measure of plant water standing. Maximum RWC was evidenced in genotype JS97-52 (68.72%) strongly tracked by a group of four genotypes *viz.*, AMS 2014-1(65.86%), PS1613 (64.88%), NRC-147(64.77%) and RVS-24 (64.08%). A group of eight genotypes including JS93-05 (61.99%), JS95-60 (63.04%), AMS-100-39(63.01%), KDS980(60.96%), RSC-10-70 (60.31%), RSC10-52(60.24%), MACS-58 (60.157%) and JS20-94 (60.38%) having RWC more than 60%. The lowest RWC was exhibited by genotype PS1092 (17.06%) intimately trailed by a group of statically *at par* three genotypes, namely: JS20-34 (19.47%), JS20-71 (21.27%)

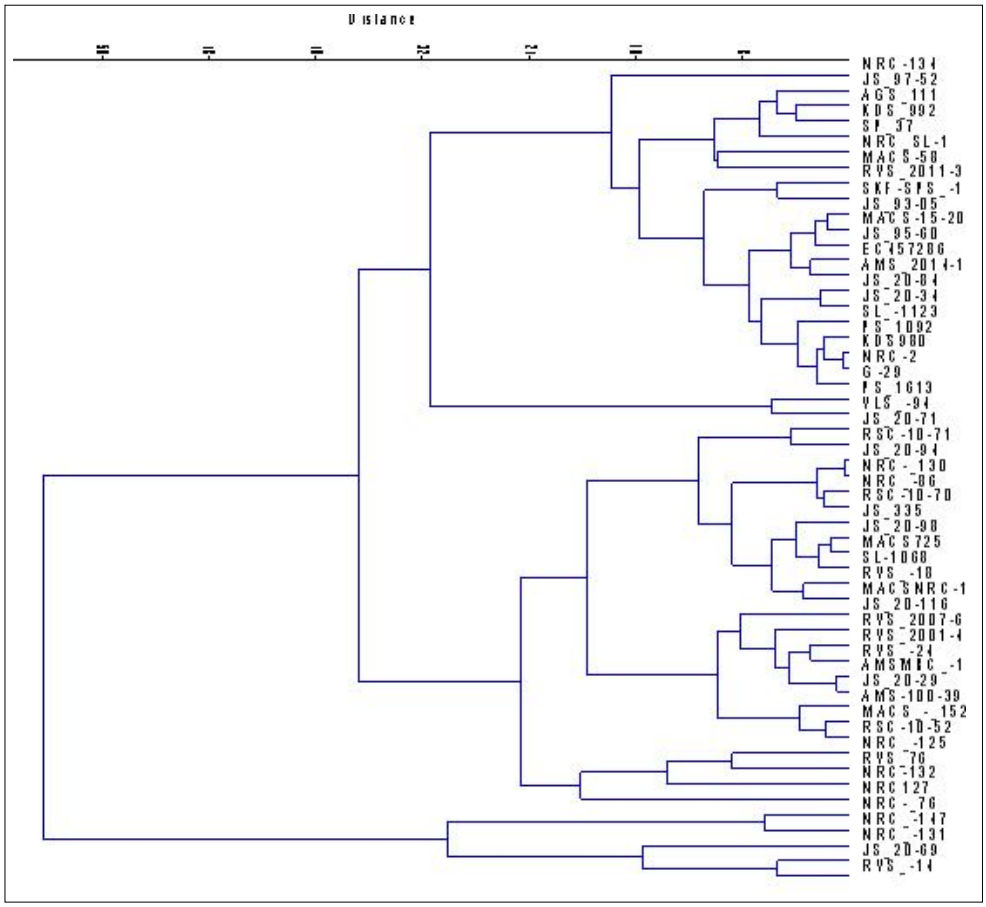


Fig 1: Dendrogram showing relationship among 53 different soybean genotypes based on different morpho-physiological traits (plant height, shoot and root length and root/shoot ratio).

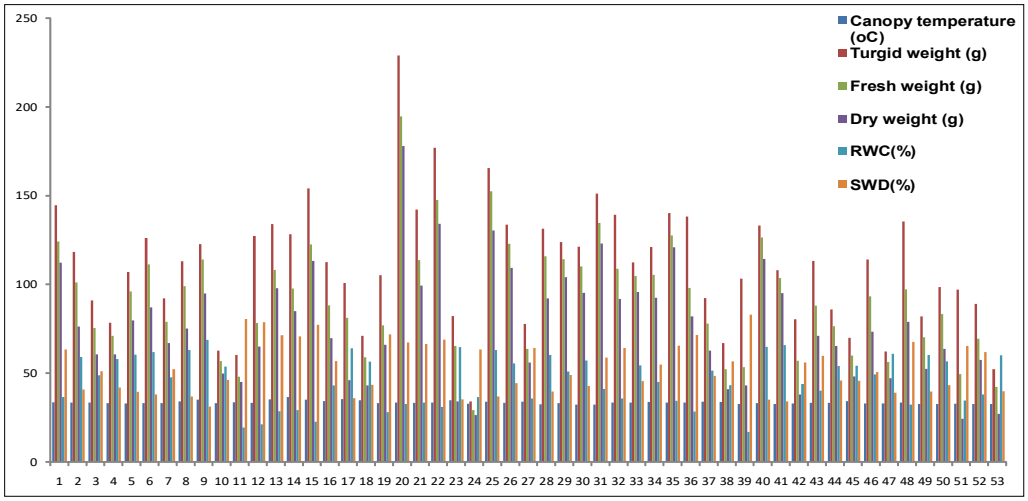


Fig 2: Graphical presentation for Canopy temperature, turgid, fresh and dry weights, RCW % and SWD % trait analysis.

and RVS2001-4 (22.74%). In the present investigation, RWC consistently decreased with susceptible genotypes in comparison to tolerant genotypes. The reducing trend of relative water content for all the genotypes may be attributed towards the reduction in external water potential (Datta *et al.,* 2011). All the genotypes showed significant variations in RWC which suggested that different cultivars have different threshold levels to retain the water status (Datta *et al.,* 2011). In the present study, RWC was higher in those genotypes may be drought tolerant as proposed by Hossain *et al*. (2014), Sepanlo *et al*. (2014) and Kachare (2017).

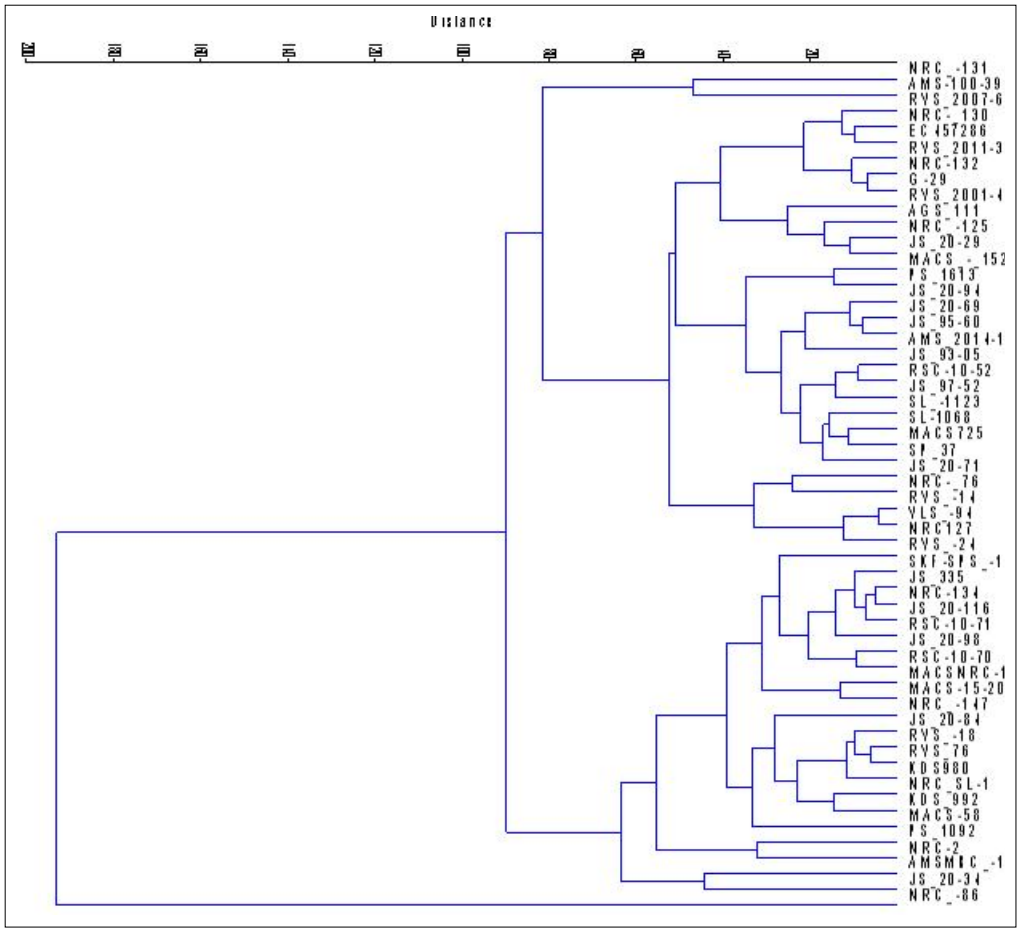


Fig 3: Dendrogram showing relationship among soybean genotypes based on different morpho-physiological traits (Canopy temperature, turgid, fresh and dry weights, RWC% and SWD%).

Minimum SWD was documented for the genotype JS 97-52 (31.27%) intimately chased by a group of four genotypes including AMS2014-1(34.14%), PS1613 (35.12%), NRC-147 (35.23%) and RVS-24 (35.92%). A group of eight genotypes *viz*., JS 93-05 (38.01%), JS 95-60 (36.96%), AMS-100-39 (36.99%), RSC10-52 (39.76%), KDS980 (39.04%), RSC-10-70 (39.69%), MACS-58 (39.85%) and JS 20-94 (39.62%) having SWD less than 40%. The highest SWD was exhibited by genotype PS1092 (82.94%) strongly tracked by a group of statically *at par* three genotypes, *i.e.*, JS20-34 (80.53%), JS20-71 (78.73%) and RVS2001-4 (67.26%). During the present study, all the susceptible genotypes exhibited significant higher values of SWD, however, tolerant genotypes exhibited lower value of SWD as compared to susceptible one. Souza *et al*. (2013) and Kachare (2017) reported similar trend in SWD for the soybean genotypes.

Based on cluster analysis of morpho-physiological traits (canopy temperature, turgid, fresh and dry weights, RWC% and SWD%) all 53 soybean genotypes structured in to two groups. Major group consisted 52 genotypes while NRC-86 grouped distantly. The major group was further divided into two sub groups with 30 and 21 genotypes respectively. First sub group was divided into two parts. Major part contained 28 soybean genotypes, *namely*: RVS2007-8, NRC-130, EC457286, RVS2011-3, NRC-132, G-29, RVS2001-4, AGS-111, NRC-125, JS20-29, MACS-152, PS-1613, JS20-94, JS20-69, JS95-60, AMS2014-1, JS93-05, RSC-10-52, JS 97-52, SL-1123, SL-1068, MACS-725, SP-37, JS20-71, NRC-76, RVS-14, VLS-94 and NRC-127 while minor part had only two genotypes *i.e.*, NRC-132 and AMS-100-39. Similarly, second sub group was further divided into two parts and major part consisted 19 genotypes, *i.e.*, RVS-24, SKF-SPS-1, JS-335, NRC-134, JS20-116, RSC-10-71, JS20-98, RSC-10-70, JS20-98, MACSNRC-1, MACS-15-20, NRC-147, JS20-84, RVS-18, RVS-78, KDS-980, NRC SL-1, KDS-992, MACS-58, PS-1092 and NRC-2 while minor part had only two genotypes AMSMBC-1 and JS20-34 (Fig 3).

CONCLUSION

On the basis of the current findings, it can be suggested that drought stress impedes the growth and metabolic activity of soybean genotypes. These traits confirmed presence of substantial variability under drought stress at diverse growth phases. This investigation may assist to recognize a number of adaptive devices expanded by soybean genotypes and donate to recognize valuable

parameters for soybean breeding programmes. In conclusion genotypes *viz.*, JS97-52, AMS 2014-1, RVS-14 and NRC-147 were found as drought tolerant. Although the contracted genetic diversity detected among soybean germplasms collection in current investigation dictate the necessitate of lengthening genetic diversity by commencing more exotic germplasm lines along with exploitation of wild relatives, the assorted genotypes identified in this research may dish up as source of new alleles in soybean breeding programme for further improving of the crop by breeding and /or biotechnological means.

Conflict of interest

All authors declared that there is no conflict of interest.

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