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# Early evaluation of wild *Hevea* germplasm for drought tolerance based on growth and dry matter production

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## Abstract

In India, extension of rubber cultivation to non- traditional and marginal areas have necessitated development of clones capable of withstanding drought situation along with other environmental stresses prevailing in these regions. Since the extent of genetic variability for such traits is rather low in the current breeding pool, the focus is on the wild Hevea germplasm collection, to identify sources of variability for drought tolerance. The present investigation was made for evaluating certain wild accessions with reference to a set of drought related growth characters both in the field and in a glasshouse. In the field, 18 months old plants under irrigation were used for assessing the genotypic difference for growth and vigour. The parameters recorded were scion height (cm), basal diameter of scion (mm), number of leaves, number of leaf flushes, interflush distance (cm), single leaflet area ($cm^2$) and specific leaf weight (SLW). Ten months old plants under water stress and irrigated conditions were used for the glasshouse study for recording the basal diameter of scion (mm) as well as fresh and dry weight of the scion (g). Growth depression consequent to water stress and the dry matter stress tolerance index (DMSI) were computed. Individual performance of the accessions was assessed by summing up the rank values for each character, based on the parametric relationship of these characters to drought tolerance. There was wide variability for all the traits studied except specific leaf weight. The usefulness of growth related parameters for early screening of germplasm for drought tolerance is discussed.

*Key words:* Rubber, germplasm, drought tolerance, dry matter stress tolerance index

## Introduction

Throughout the world, rubber plantations are raised under rain fed conditions. But there is only limited scope of expansion of the crop in its favoured traditional belt. So attempts are being made to extend this tree even to marginal areas to cope with the increasing global demand for natural rubber. In these marginal areas the major limitation is the climatic constraints such as prolonged soil moisture stress and high ambient day temperatures (Sethuraj *et al.*, 1989). Soil and atmospheric drought and high temperature are major environmental factors limiting growth and yield in *Hevea*. Hence development of a suitable drought tolerant *Hevea* clone is highly essential for cultivation in the drought prone areas. The very narrow genetic base of the cultivated *Hevea* species is the major limitation for further crop improvement programme. Widening of this narrow genetic base can be achieved by introgression of appropriate alien genes from the wild progenitors. Several investigations on drought resistance in crop plants have led to the observation that wild relatives of cultivated species are drought tolerant (Shimshi *et al.*, 1982). The wild genotypes of *Hevea* collected through IRRDB expedition in 1981 into the primary center of origin of the crop, the Amazon forests, is a good resource of variability. Around 4500 accessions of this wild Brazilian germplasm are being conserved in India. The exploration covered a wide range of agro climatic areas in the three Brazilian states Acre (AC), Rondonia (RO) and Mato Grosso (MT). This wild germplasm is a potential source of genetic variability and hence a screening of this material for identifying suitable accessions with drought tolerance will be ideal for developing a drought tolerant *Hevea* clone by incorporating the gene for drought tolerance from the wild accession to the cultivating clone. In order to develop effective screening techniques it is important to know the major mechanisms associated with drought tolerance and to know which traits may be utilized in a breeding programme. The greatest potential in breeding and selection for adaptation to drought seems to lie in specific processes controlled by one or a few genes rather than integrated traits controlled by many genes. Hence, selection at genotypic level offers possibility to evolve suitable drought tolerant varieties by conducting screening using various morphological, physiological, anatomical and biochemical indices which have a relationship with drought tolerance.

There are various reports on the effect of drought on growth and yield of rubber. De Conceicao *et al.*, (1986) noticed a reduction in growth and assimilate partitioning when *Hevea* clones were subjected to water deficit. In a study conducted by Rao *et al.* (1990) on yield and yield components of *Hevea* clones during water stress in 1987, significant variations in yield components between the two clones RRII 105 and RRII 118 were noticed. In an analysis of growth and drought tolerance in rubber during the immature phase in a dry subhumid climate, Chandrashekar *et al.*, (1998) noticed that a large portion of growth has occurred in the wet season while during the dry season the growth rates of the clones declined substantially. Most of the clones showed the same trend in girthing pattern also. Various other reports also suggest the changes occurring to plant stem, leaf and dry matter partitioning as a result of water stress. Hence the present study was undertaken to evaluate the usefulness of some of the morphological traits for screening of germplasm for drought tolerance and to assess the genetic variability among the selected wild *Hevea* accessions for drought related parameters in an early growth phase.

## Materials and Methods

Wild germplasm material conserved in the source bush nursery of Central Experimental Station (CES) of Rubber Research Institute of India (RRII) constituted the base material for the present study. Ten accessions were selected based on preliminary studies conducted among 450 accessions for growth parameters during summer months. They were multiplied along with the standard clones viz., RRII 105 (popular high yielding clone), RRIM 600 (known drought tolerant clone) and Tjir 1 (known drought susceptible clone) and established in polythene bags of lay flat dimension of 55 cm length, 25 cm width and 400 gauge thickness. The budded stumps planted in the polythene bags were irrigated till they were established. Studies were conducted both in the field and in a glasshouse by adopting a completely randomised design with 3 plants/plot replicated 4 times, to assess the genotypic difference among the selected accessions for growth and vigour under water stress. The parameters recorded in the field experiment in 18 months old plants include scion height (cm), basal diameter of scion at 20 cm from bud union (mm), number of leaves, number of leaf flushes, interflush distance (cm), single leaflet area ($cm^2$) using LI-3100 area meter (Licor Instruments, USA) and specific leaf weight (SLW) ($mg.cm^{-2}$) using middle leaflet area and their dry weight after oven drying at 80°C for two days.

For the glasshouse study a complete set of the selected accessions were grown in the glasshouse. After the establishment of the plants, at the age of 10 montl they were divided into two sets. In one set irrigation was given on alternate days, and in the second set, irrigation was withheld for 60 days. Before inducing water stress, basal diameter of scion was measured in both the sets. At the end of two months stress period (60 days) the following morphological observations were recorded from both sets.

1. Basal diameter of scion (mm)
2. Fresh weight of the scion (g)
3. Dry weight of the scion (g)

Dry matter stress tolerance index(DMSI) was worked out as follows:

$$\text{DMSI} = \frac{\text{Dry matter of non stressed plants - Dry matter of stressed plants}}{\text{Dry matter of non stressed plants}} \times 100$$

Data were subjected to analysis of variance and based on the F value, accessions were ranked following Duncan's multiple range test. Performance of each of the accession was assessed by summing up of the rank values obtained for each character, based on the relationship of these characters to drought tolerance (Singh and Choudhary, 1985).

## Results and Discussion

### *a. Field experiment*

In *Hevea* growth and yield are affected under drought conditions and hence, clones with good growth and vigor in the early growth stage are highly preferred for drought-affected areas. There are several earlier reports indicating the importance and usefulness of morphological characters like plant height, basal diameter, number of leaves, leaf area etc. in water stressed or drought condition (De Conceicao *et al.*, 1986). These characters give an indication of the general vigor of the genotype and hence studying these characters at the juvenile stage itself hold some importance.

The significant genotypic difference observed in almost all the morphological characters studied among the wild genotypes (Table. 1) indicated the wide genetic base of this material, which is highly useful for crop improvement. Plant height, which is an indication of rate of growth, among the accessions, varied from 99.22 to 147.06 cm with a mean height of 118.31 cm. The tallest genotype was MT55, whereas the shortest was AC 652. The clones RRIM 600 and Tjir 1 had comparable heights, whereas clone RRII 105 recorded a higher value. In general, the wild accessions were taller than the Wickham clones. Pollinere (1996) reported that among the morphological components of yield, girth is considered as the most important parameter of growth and vigour in rubber. Hence, recording of basal diameter in the juvenile stage is important to assess the general vigour of the wild accession. Basal diameter was the highest in AC 650 (15.79 mm) followed by MT 66 and lowest in AC 652 (10.14 mm) with a mean of 12.47mm.

Though there were numerical differences in basal diameter between accessions the difference was not significant. The plant height and basal diameter in the juvenile phase give an indication of the general vigour of the plant and reports suggest that there will be a reduction in both as a result of water stress (Powell, 1976). Hence the accessions with high values for these characters in the juvenile stage are indicative of its potential for good growth even in the drought situation. In a study with apple trees, Chandal and Chauhan, (1990) observed increased tree height, shoot growth, tree spread and trunk girth under low moisture stress.

Rate of production of leaves is another indicator of the vigour of the plants in the active growth phase. Total number of leaves present among the genotypes studied varied from 33.45 to 99.72 with a mean of 63.88. MT 41 recorded the highest number of leaves followed by AC 650, whereas the lowest number of leaves was present in AC 652 followed by MT 66. Analysis of variance indicated significant genotypic difference for this character. Number of flushes among the wild genotypes also exhibited significant genotypic difference. The mean number of flushes was 2.64 with a range of 1.78-3.81. The minimum number of flushes was recorded in AC 652, whereas MT 41 possessed the maximum number of flushes, followed by MT 55. The number of flushes in the clones RRIM 600, Tjir 1 and RRII 105 were comparable. The maximum number of leaves and leaf flushes in the wild accession MT 41 along with comparatively high basal diameter and plant height indicate the vigorous growth habit of this accession. Such accessions are highly suitable for drought prone area. In apple trees Yang-Sang Jin *et al.*, (1996) noticed decreased shoot length and leaf area and increased fruit

**Table 1. Morphological parameters of selected accessions**

| Genotypes | Plant height (cm) | Basal diameter (mm) | No. of flushes | No. of leaves | Inter flush distance (cm) | Single leaflet area ($cm^2$) | SLW($g\ cm^{-2}$) |
|---|---|---|---|---|---|---|---|
| AC 1044 | 102.79 $^{c}$ | 11.14 $^{ab}$ | 2.08 $^{cd}$ | 49 $^{de}$ | 28.05 $^{ab}$ | 84.42 $^{a}$ | 0.005 $^{a}$ |
| MT 55 | 147.06 $^{a}$ | 13.23 $^{ab}$ | 3.06 $^{abc}$ | 90.89 $^{abc}$ | 28.77 $^{ab}$ | 87.05 $^{a}$ | 0.006 $^{a}$ |
| AC 446 | 115.77 $^{abc}$ | 13.49 $^{ab}$ | 2.83 $^{abcd}$ | 48.47 $^{de}$ | 35.26 $^{ab}$ | 86.84 $^{a}$ | 0.005 $^{a}$ |
| RRIM 600 | 104.95 $^{c}$ | 11.61 $^{ab}$ | 2.28 $^{bcd}$ | 51.44 $^{de}$ | 22.67 $^{b}$ | 58.82 $^{b}$ | 0.006 $^{a}$ |
| Tjir 1 | 104.9 $^{c}$ | 11.89 $^{ab}$ | 2.61 $^{bcd}$ | 70.92 $^{abcd}$ | 22.18 $^{b}$ | 59.30 $^{b}$ | 0.007 $^{a}$ |
| MT 41 | 144.53 $^{ab}$ | 12.88 $^{ab}$ | 3.81 $^{a}$ | 99.72 $^{a}$ | 24.07 $^{b}$ | 83.08 $^{a}$ | 0.006 $^{a}$ |
| MT 76 | 144.06 $^{ab}$ | 12.02 $^{ab}$ | 3 $^{abc}$ | 77.22 $^{abcd}$ | 28.59 $^{ab}$ | 60.85 $^{b}$ | 0.006 $^{a}$ |
| MT 66 | 99.75 $^{c}$ | 13.63 $^{ab}$ | 2.69 $^{bcd}$ | 48.25 $^{de}$ | 19.57 $^{b}$ | 81.56 $^{a}$ | 0.007 $^{a}$ |
| MT 938 | 130.67 $^{abc}$ | 11.5 $^{ab}$ | 2.17 $^{cd}$ | 60.33 $^{bcde}$ | 43.92 $^{a}$ | 84.8 $^{a}$ | 0.006 $^{a}$ |
| AC 650 | 123.68 $^{abc}$ | 15.79 $^{a}$ | 3.36 $^{ab}$ | 95.25 $^{ab}$ | 32.51 $^{ab}$ | 83.22 $^{a}$ | 0.007 $^{a}$ |
| AC 652 | 99.22 $^{c}$ | 10.14 $^{b}$ | 1.78 $^{d}$ | 33.45 | 21.72 $^{b}$ | 80.44 $^{a}$ | 0.006 $^{a}$ |
| RRII 105 | 108.31 $^{bc}$ | 11.66 $^{ab}$ | 2.25 $^{bcd}$ | 50.08 $^{de}$ | 20.15 $^{b}$ | 61.52 $^{b}$ | 0.007 $^{a}$ |
| AC 728 | 112.29 $^{abc}$ | 13.1 $^{ab}$ | 2.33 $^{bcd}$ | 55.44 $^{cde}$ | 24.47 $^{b}$ | 90.78 $^{a}$ | 0.005 $^{a}$ |
| G mean | 118.31 | 12.47 | 2.64 | 63.88 | 27.07 | 76.784 | 0.006 |

Any two means having a common letter are not significantly different drop and leaf fall with increasing water stress. Similarly Byari and Al-Rabighi, (1996) studied the effect of water deficit treatments on plant height, leaf area, number of leaves and number of branches in eggplant cultivars and found a significant reduction in all these characters as a result of water stress.

Leaf area is another important character to ascertain the photosynthetic capacity of the plants. The total leaf area is sometimes referred to as its photosynthetic potential (Ticha, 1985). In the improvement of plantation crops like rubber, effort have to be to bring light interception to 100% but without making the lower leaves parasitic. A plant having large leaves at the top could intercept almost all the light but would result in so much shading that the efficiency of lower leaves would be reduced. Therefore selection for smaller leaves may provide a better plant canopy for higher photosynthetic efficiency. It has been reported that a small leaf size and greater leaf thickness are correlated to higher photosynthetic rate (Swaminathan, 1977). Single leaflet area of the accessions in the present study exhibited significant genotypic difference. Wild genotypes in general recorded higher leaf area than the cultivated clones. The highest leaflet area recorded was 90.78 $cm^2$ in the accession AC 728 and the lowest was in MT 76 with a mean of 76.784 $cm^2$., indicating the genetic variation present among these accessions for the available transpirational area which in turn helps the plants to adapt to periods of drought by reducing the transpirational loss. Genetic variation in leaf expansion rate among cocoa accessions under water stress has been reported by Balasimha (1987) and Joly and Hahn, 1989 suggested that the reduction in leaf area in cocoa plants help them to adapt to periods of drought Chandrashekar *et al.*, (1990) noticed partial defoliation and leaf margin drying in *Hevea* clones during the summer periods in the non-traditional rubber growing area of North Konkan region as a part of reducing the total leaf area. In drought susceptible coconut genotypes the number of drooping leaves was higher under water stress condition (Rajagopal *et al.*, 1990). All these reports suggest the importance of reduced leaf area under water stress condition. In the present study accessions like MT 76 and MT 41 with reduced leaf area are suitable for a water stressed condition.

The mean interflush distance recorded was 27.07cm with a range of 19.57 (MT 66) - 43.92 cm (MT 938). However, the differences were not significant in the Wickham clones of RRIM 600, Tjir 1 and RRII 105. The inter flush distance indicates the transportation distance and hence a low interflush distance is a positive sign where the translocation as well as partitioning of photosynthates will be more effective. In addition to that they can provide mutual shading also. So the low interflush distance recorded in the accessions MT 41, MT 76, MT 66 and AC 652 can be of more advantageous under drought stress conditions.

Specific leaf weight also did not show any significant difference among the genotypes. SLW among wild accessions ranged from 0.0005 - 0.0007 $mgcm^{-2}$ with a mean of 0.0006 $mgcm^{-2}$ while Tjir 1 and RRII 105 recorded 0.0007 $mgcm^{-2}$ whereas in RRIM 600 the value was 0.0006 $mgcm^{-2}$. In cocoa accessions, Balasimha, (1987) observed that the drought tolerant ones were those with high SLW. So the accessions with high SLW are preferred under drought conditions hence the comparatively higher SLW noticed in the wild genotypes MT 55, MT 41, MT 76, MT 66, MT 938, AC 650 and AC 652 would be a valuable trait for selection in germplasm material. In this study majority of the accessions with higher SLW appeared to be of Mato Grosso Provenance highlighting their superiority under drought condition.

In the present study, the wild genotypes expressed high genetic variation for almost all the growth characters recorded and this wide range of inherent genetic variability is mainly because of its genetically unexploited and unaltered nature. Generally the accessions with good growth and vigour in the early growth phase are advantageous for making early selection. The genetic difference in the three control clones RRIM 600, RRII 105 and Tjir 1 was nil except for number of leaves. This reveals the broader genetic base of wild germplasm in comparison with the Wickham clones reflecting the potential of this material for utilization in crop improvement programmes leading to the development of location specific clones.

***b. Glass house experiment***

***Effect of water stress on basal diameter***

The effect of water stress on basal diameter (girth) was studied in the clones both under water stress and non stress conditions (Table. 2). The results revealed significant genotypic difference for growth rate in basal diameter under water stress. Under non stress, all the accessions showed increase in basal diameter as expected. The maximum growth (as percent increase in basal diameter) was recorded in the wild accession MT

**Table 2. Influence of water stress on basal diameter of selected genotypes**

| Genotypes | Non-stress (Treatment set) | Stress (for 60 days) | increase / decrease (%) over 60 days | Basal diameter (mm)Increase Non-stress-1 (Control set) | Non-stress-2 (for 60 days) | Growth (%) over 60 days | depression |
|---|---|---|---|---|---|---|---|
| AC 1044 | 7.2 | 6.999 | $-6.97^{f}$ | 7.2 | 7.8 | 8.33 | 15.297 |
| MT 55 | 7.13 | 6.987 | $-2^{d}$ | 8.07 | 8.67 | 6.92 | 8.92 |
| AC 446 | 7.63 | 7.433 | -2.6 d$^{e}$ | 8.5 | 8.77 | 3.08 | 5.677 |
| RRIM 600 | 7.09 | 6.977 | $-1.59^{d}$ | 7.57 | 8.1 | 7 | 8.587 |
| Tjir 1 | 6.68 | 6.57 | $-1.66^{d}$ | 6.5 | 7.53 | 15.85 | 17.513 |
| MT 41 | 7.19 | 7.478 | $4.03^{a}$ | 7.17 | 7.97 | 11.16 | 7.127 |
| MT76 | 7.3 | 7.767 | $0.65^{bc}$ | 7.25 | 7.96 | 8.92 | 8.273 |
| MT 66 | 6.24 | 6.47 | $0.37^{c}$ | 6.67 | 7.5 | 12.44 | 12.07 |
| MT 938 | 7.9 | 8.01 | $1.36^{bc}$ | 7.4 | 8 | 7.5 | 6.137 |
| AC 650 | 7.68 | 7.534 | $-1.95^{d}$ | 7.57 | 8.27 | 9.25 | 11.203 |
| AC 652 | 7.43 | 7.57 | $1.96^{b}$ | 7.1 | 7.43 | 4.44 | 2.483 |
| RRII 105 | 7.57 | 7.29 | $-3.66^{f}$ | 6.97 | 7.5 | 7.6 | 11.257 |
| AC 728 | 7.61 | 7.389 | $-2.93^{de}$ | 7.8 | 8.37 | 7.31 | 10.243 |
| Mean | 7.28 | 6.685 | -1.15 | 7.37 | 7.99 | 8.45 | 9.599 |

Any two means having a common letter are not significantly different

66 (12.4%) followed by MT 41 (11.2%). Under water stress, though there was a reduction in the basal diameter in 50 percent of the accessions (AC 1044, MT 55, AC 446, AC 650, AC 728) the remaining 50 percent of the accessions (MT 41, MT 76, MT 66, MT 938, AC 652) mostly from Mato Grosso Provenance interestingly showed an increase in basal diameter. The maximum growth under water stress with respect to girth was recorded by MT 41 (an increase of 4%) and the most affected one was AC 1044 (a decrease of 7%). Girth reduction in *Hevea* clones as a result of water stress has been reported earlier (Chandrashekar et al. 1998) and the result obtained in the present study also confirms the earlier reports. However, the increase in girth exhibited by MT 41 even under water stress, highlights the genetic potential and the suitability of this accession for a drought prone area. The superior performance of this accession in the field study also confirms this.

Growth depression occurred in these accessions as a result of water stress was calculated (as percent) by considering the growth rate in each accession under stressed and non-stressed condition. The maximum growth depression among the wild accessions was observed in AC 1044 (15.3%) as the growth rate of this accession under water stress was severely affected. The lowest growth depression was recorded in AC 652 (2.5%) followed by AC 446 (5.7%) and MT 41(7%). The highest growth depression showed by Tjir 1 (17.5%) among the control clones explains the drought susceptibility of this clone. The decreased growth rate (3.7%) under water stress leading to higher growth depression (11%) in RRII 105 compared to RRIM 600 confirms the drought susceptibility of RRII 105 and drought tolerance of RRIM 600 with respect to growth.

### *Effect of water stress on dry matter production*

Leaf area and dry matter are the two plant characters that determine the total biological productivity, but partitioning of the total biological yield is the most important inherent character that determines the economic yield (Donald and Hamblin, 1976). In coconut palms under severe moisture stress, dry matter production was reduced by 22% compared with well-watered palms (Rajagopal *et al.*, 1989). Significant reduction in dry matter as a result of drought stress has been reported in various other crops like tea (Burgess and Carr, 1996), maize (Celiz *et al.*, 1995), field bean and field pea (Grzesiak *et al.*, 1997), eggplant (Byari and Al-Rabighi, 1996) and *Hevea* (Vijayakumar *et al.*, 1998).

In the present study also there was a reduction in the dry matter production under water stress (Table. 3). Under non-stress condition, almost all the genotypes produced more or less similar dry matter. The range varied from 17.93-28.1 g with a mean of 22.63 g and the highest dry matter production was recorded in the accession MT 938 followed by AC 1044 while the lowest was in AC 652. All the three standard clones recorded comparable dry matter production which was similar to the mean value. However, under water stress the wild genotypes as well as the control clones reacted differently. The dry matter production was considerably reduced in all the genotypes. The range was between 6.97 - 19.83 g with a mean value of 11.77 g. Though there was significant reduction in dry matter in all the control clones, the reduction was so drastic in the clone Tjir1. Analysis of data indicated significant genotypic difference.

The dry weight of the scion portion under non-stress and stress conditions were considered for calculating the dry matter stress tolerance index (DMSI), which gives an indication of stress tolerance level. In coconut, intensity of drought has been assessed by the drought tolerance index (Pomier and de Taffin, 1982) or by the aridity index (Prasada Rao, 1985) based on the reduction in the number of leaves and nuts during drought situations. The range in DMSI varied from 27.85 to 71.7 with a mean of 47.99 and the genotypic difference was significant. The highest stress tolerance in terms of DMSI was noticed in the wild accession AC 652 (27.85) followed by MT 41 (31.8) whereas, the lowest was in MT 66 (63.99) followed by MT 55 (64.51). Low DMSI value for AC 652 and MT 41 indicate their ability to produce more dry matter even at water stress condition. The tolerance index in the control clones RRIM 600 and RRII 105 were 56.25 and 40.34 and that of Tjir 1 was 71.7. The highest DMSI for the clone Tjir 1 reveals its drought susceptibility. The genetic variability present in the wild germplasm materials for DMSI again points out the genetic potential of germplasm materials for making desirable selections for drought resistance breeding.

**Table 3. Dry matter stress tolerance index (DMSI) of selected accessions**

| Genotypes | Non-stress (g) | Stress (g) | DMSI |
|---|---|---|---|
| AC 1044 | 26.1 $^{ab}$ | 12.33 $^{b}$ | 53.86 $^{bc}$ |
| MT 55 | 26.01 $^{ab}$ | 9.27 $^{b}$ | 63.99 $^{ab}$ |
| AC 446 | 21.7 $^{ab}$ | 14.01 $^{ab}$ | 35.79 $^{def}$ |
| RRIM 600 | 23.93 $^{ab}$ | 10.57 $^{b}$ | 56.25 $^{b}$ |
| Tjir 1 | 24.62 $^{ab}$ | 6.97 $^{b}$ | 71.7 $^{a}$ |
| MT 41 | 19.02 $^{b}$ | 13 $^{b}$ | 31.8 $^{def}$ |
| MT76 | 23.37 $^{ab}$ | 13.39 $^{b}$ | 43.65 $^{cd}$ |
| MT 66 | 21.63 $^{ab}$ | 7.67 $^{b}$ | 64.51 $^{ab}$ |
| MT 938 | 28.1 $^{a}$ | 19.83 $^{a}$ | 30.49 $^{ef}$ |
| AC 650 | 18.87 $^{b}$ | 7.5 $^{b}$ | 60.5 $^{ab}$ |
| AC 652 | 17.93 $^{b}$ | 13.13 $^{b}$ | 27.85 $^{f}$ |
| RRII 105 | 21.33 $^{ab}$ | 12.87 $^{b}$ | 40.34 $^{de}$ |
| AC 728 | 21.61 $^{ab}$ | 12.47 $^{b}$ | 43.23 $^{cd}$ |
| G mean | 22.63 | 11.77 | 47.99 |

Any two means having a common letter are not significantly different

***Identification of superior accessions based on rank sums***

Adaptation of a clone to drought tolerance is a cumulative effect of all the related traits. Ranking of each accession based on the relationship of all the characters is quite useful for assessing the actual worthiness of each accession. In the present study ranking was done separately for the field and the glass house experiments (Table. 4). In the field study, the growth characters plant height, basal diameter, number of flushes, inter flush distance and leaf area were used for ranking whereas, in the glass house study the parameters viz; the growth rate, growth depression and dry matter stress tolerance index under water stress were considered. The rank sums varied from 22 to 49 in the field study and the first five top ranking accessions were MT 41, AC 650, MT 76, MT 55 and MT 66. The range for rank sum varied from 5 to 20 in the glass house study and the five top ranking accessions were MT

**Table 4. Ranking of accessions for selected characters with relation to drought tolerance**

| Accession | Field study | | | | | | Glass house study | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Plant height | Basal diameter | No. flushes | Interflush dis. | Leaf area | Rank Sum | Growth rate | Growth depress-ion | DMSI | Rank Sum | Final Rank |
| AC 1044 | 3 | 2 | 2 | 6 | 5 | 22 | 1 | 1 | 3 | 5 | 7 |
| MT 55 | 10 | 7 | 8 | 4 | 2 | 39 | 4 | 5 | 7 | 16 | 5 |
| AC 446 | 5 | 8 | 6 | 2 | 3 | 27 | 3 | 9 | 4 | 16 | 5 |
| MT 41 | 9 | 5 | 10 | 8 | 7 | 49 | 10 | 7 | 3 | 20 | 1 |
| MT 76 | 8 | 4 | 7 | 5 | 10 | 41 | 7 | 6 | 6 | 19 | 2 |
| MT 66 | 2 | 9 | 5 | 10 | 8 | 36 | 6 | 2 | 10 | 18 | 3 |
| MT 938 | 7 | 3 | 3 | 1 | 4 | 24 | 8 | 8 | 2 | 18 | 3 |
| AC 650 | 6 | 10 | 9 | 3 | 6 | 45 | 5 | 3 | 9 | 17 | 4 |
| AC 652 | 1 | 1 | 1 | 9 | 9 | 22 | 9 | 10 | 1 | 20 | 1 |
| AC 728 | 4 | 6 | 4 | 7 | 1 | 27 | 2 | 4 | 5 | 11 | 6 |

AC 652, MT 76, MT 66and MT 938. In both the ranking, three accessions MT 41, MT 76 and MT 66 were common, suggesting the general superiority of these accessions irrespective of their growth conditions. The top most rank obtained for MT 41 in both the studies indicates the potential of this accession for a drought prone area. The results of the ranking in both conditions (water stress and non stress) of the present study clearly indicate that accessions with good growth and vigour in the early growth phase can be selected for a drought prone area as they will continue to show their superiority even under a stress condition.

## Conclusions

The results reveal existence of wide genetic variability among the wild germplasm accessions for various growth parameters such as scion height (cm), scion basal diameter (mm), number of leaves, number of leaf flushes and single leaflet area (cm2) in the early growth phase. Dry matter production and dry matter stress tolerance index also give an indication towards the stress tolerance capacity of the wild accessions. These parameters contributing to general vigour of an accession in the early growth phase can be employed for screening the large number of germplasm materials for drought tolerance.

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