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# Morpho-Physiological Traits Influencing the Grain Yield Potential in Small Millets

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**An experiment was conducted to study the certain morphological and physiological traits influencing the grain yield potential of small millets under irrigated condition. Out of six cultivated small millets, five of them *viz.,* finger millet (CO15), little millet (CO 4), barnyard millet (CO 2), foxtail millet (CO 7) and kodo millet (CO 3) was taken for the study. The experiment was conducted during *Rabi,* 2015 in Completely Randomized Design (CRD) with four replications. The results indicated significant differences among the small millets in plant height, number of tillers per plant, LAI and LAD. The gas exchange parameters differed significantly among the crops leading to significant variation in total dry mater accumulation. However, the productivity was not only dependent on higher values of physiological traits but also on partitioning efficiency and test weight. Leaf area indices at different stages of growth were significantly higher in barnyard millet and it was followed by foxtail millet. Leaf area duration between vegetative to flowering stages was maximum in foxtail millet (48.54 days) and the minimum was observed in kodo millet (15.32 days). The barnyard millet, finger millet and foxtail millet had higher values for most of the physiological traits and yield components leading to higher grain yield when compared to other small millets.**

**Key words:** Small millets, Morphological parameters, Gas exchange parameters, Yield Traits

The Poaceae family contains number of small seeded species known as millets. Millet is a general term for a wide range of small seeded cereals (Marcon, 1994) that may be used for grain and/or forage (Schery, 1972). In India, commonly grown millets include sorghum, pearl millet, finger millet, foxtail millet, little millet, barnyard millet, proso millet, and kodo millet. Sorghum and pearl millet are considered as coarse millet, while the other six crops comprised of small millet group (Gupta *et al.,* 2010). In general, the productivity of small millets is lower than the major cereal crops. Finger millet has been predominantly grown in Southern Asia and Eastern Africa, both for grain and forage (Gupta *et al.,* 2010). It is most important small millet in tropics (12 % of global millet area) and is cultivated in more than 25 countries in Africa (eastern and southern) and Asia (from Near East to Far East), predominantly (ICRISAT, 2011a). Finger millet grains can be stored for years without being infested by storage pest, which makes it a perfect food grain commodity for famine prone areas (National Research Council USA, 1996). Foxtail millet ranks second among the millet produced globally. World's total production of foxtail millet was estimated to be five million tons (Lin, 2005) with China being the main producer (3.7 million tons). Foxtail millet is fairly tolerant to drought; it can escape some droughts because of early maturity. Due to its short life cycle, it can be grown as a short-term catch crop (ICRISAT 2011b). It is also cultivated as a dry land crop under marginal and sub-marginal lands (Rao *et al.,* 1997). It requires water in the later stages of the crop growth but cannot tolerate water logging (Jijau, 1989). Little millet is an important crop grown for food and feed in the tribal belt of Madhya Pradesh, Chattisgarh and Andhra Pradesh in India (Haider, 1997). It is described as a quick growing, short duration cereals, which can withstand both drought and water logging (Dogget, 1989). Kodo millet is grown as a cereal in India only. Kodo millet is a long duration crop and grows well in shallow as well as deep soils (Hegde and Gowda, 1989). Barnyard millet is grown in India, Japan and China as a substitute for rice under natural precipitation. It has a wide adaptation capacity and grown up to an altitude of 2000m above mean sea level during summer season (Gupta *et al.,* 2009). Among small millets, barnyard millet is the fastest growing millet and produces a crop in 6 weeks from sowing to maturity (Padulosi *et al.,* 2009).

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## Material and Methods

A pot culture experiment was conducted at Crop Physiology Department, Tamil Nadu Agricultural University, Coimbatore during Rabi season. The experiment consisting of five crops was laid out with four replications and four stages *viz.,* seedling, vegetative, flowering and maturity. The five small millets and the varieties selected for this study are finger millet (CO 15), little millet (CO 4), barnyard millet (CO 2), foxtail millet (CO 7) and kodo millet (CO 3). The seed for the experiment was procured from Millet Breeding Station, Tamil Nadu Agricultural University, Coimbatore. Red sandy soil was used for pot culture experiment. The seeds were directly sown in the pot since minor millets used for the study are direct seeded one. The plant height, number of tillers was recorded at different growth stages. The LAI and LAD were computed by the method proposed by Williams (1946) and Power et al. (1967), respectively. The entire plant was pulled out with the root system intact at different stages to record total dry matter production. Plant samples were shade dried and then oven dried (70° C) for 48 hours. The dry weight of whole plant at different growth stages were recorded and expressed in g plant-1. Gas exchange parameters was recorded at vegetative and flowering by portable photosynthetic meter (LI-6400, Inc, Lincoln, USA). The crop was harvested at physiological maturity and grain yield was expressed in grams per plant. The yield attributing character 100 grain weight was recorded and the harvest index was calculated with the formula given by Yoshida *et al.* (1972).

### Results and Discussion

Plant type is mainly depicted from the quantitative characters of the crop such as plant height and tillers per plant. Plant height of minor millets is furnished in Table 1.

**Table 1. Plant height (cm) of small millets at different growth stages**

| Crop | Seedling stage | Vegetative stage | Flowering stage | Maturity stage |
|---|---|---|---|---|
| Finger millet | 37.60 | 58.24 | 85.55 | 95.81 |
| Little millet | 36.66 | 65.96 | 98.45 | 105.65 |
| Barnyard millet | 37.74 | 71.29 | 101.55 | 115.14 |
| Foxtail millet | 35.22 | 61.65 | 87.85 | 112.55 |
| Kodo millet | 26.80 | 46.55 | 50.55 | 62.14 |
| Mean | 34.80 | 60.73 | 84.79 | 98.25 |
| SEd | 0.446 | 0.620 | 1.308 | 1.644 |
| CD (P=0.05) | 0.950 | 1.322 | 2.789 | 3.504 |

All these values differed significantly among the five minor millets studied. The crop barnyard millet (115.14 cm) had significantly higher plant height followed by foxtail millet (112.55 cm) and significantly lower height was recorded in kodo millet (62.14 cm) at all four stages. In the present study, the high yielding capacity was found in taller plants and low yielding ones were shorter plants.

**Table 2. Total dry matter production (g plant$^{-1}$) of small millets at different growth stages**

| Crop | Seedling stage | Vegetative stage | Flowering stage | Maturity stage |
|---|---|---|---|---|
| Finger millet | 4.82 | 18.72 | 57.76 | 73.01 |
| Little millet | 4.01 | 17.41 | 35.36 | 62.82 |
| Barnyard millet | 5.95 | 19.38 | 48.05 | 85.58 |
| Foxtail millet | 4.51 | 19.01 | 39.89 | 79.95 |
| Kodo millet | 3.93 | 17.01 | 33.39 | 59.70 |
| Mean | 4.64 | 18.30 | 42.89 | 72.21 |
| SEd | 0.074 | 0.259 | 0.589 | 0.756 |
| CD (P=0.05) | 0.158 | 0.552 | 1.257 | 1.612 |

These results are in conformity with the findings of Rathod *et al. (*1996). The number of tillers per plant is considered as one of the important morphological characters directly associated with yield in millets (Acharya, 1987, Chidambaram and Palanisamy, 1996).

**Table 3. Leaf area index (LAI) of small millets at different growth stages**

| Crop | Seedling stage | Vegetative stage | Flowering stage | Maturity stage |
|---|---|---|---|---|
| Finger millet | 0.87 | 2.09 | 2.97 | 2.23 |
| Little millet | 0.82 | 1.88 | 2.64 | 2.02 |
| Barnyard millet | 1.38 | 2.53 | 3.24 | 2.75 |
| Foxtail millet | 1.19 | 2.16 | 2.88 | 2.18 |
| Kodo millet | 0.72 | 1.46 | 2.24 | 1.93 |
| Mean | 1.00 | 2.02 | 2.79 | 2.22 |
| SEd | 0.014 | 0.018 | 0.266 | 0.026 |
| CD (P=0.05) | 0.315 | 0.038 | 0.056 | 0.056 |

The high yielding genotypes recorded maximum tillers per plant. This is in accordance with the findings of Acharya (1987), Chidambaram and Palanisamy (1996). The growth parameters are furnished in Table 2, 3and 4. Leaf area index (LAI) at all the stages was significantly higher in barnyard millet (1.38, 2.53, 3.24 and 2.75) followed by foxtail millet (1.19, 2.16, 2.88 and 2.18).

The higher LAI in these genotypes may be attributed to their higher tillers per plant. A significant correlation of LAI and yield has been reported by Hanumantharao and Sathyanarayana (1987) and Bhoite (2000). Leaf area duration (LAD) indicates persistance of greenness in the crops. It is a useful growth parameter indicating the efficiency of photosynthetic system, with a high degree of association with dry matter accumulation (Chetti and Sirohi, 1995). Higher LAD has lead to higher Total Dry Matter (TDM) and grain yield. LAD in the present investigation differed significantly among the crops. It was observed that, the leaf area duration between vegetative to flowering stages was maximum in foxtail millet (48.54 days) and the minimum was observed in kodo millet (15.32 days).

**Table 4. Leaf area duration (LAD) of small millets at different growth stages**

| | Leaf area duration (days) | | |
|---|---|---|---|
| Crop | Seedling - Vegetative stage | Vegetative - Flowering stage | Flowering - Maturity stage |
| Finger millet | 29.45 | 35.48 | 34.55 |
| Little millet | 14.36 | 33.85 | 32.94 |
| Barnyard millet | 15.92 | 34.86 | 30.27 |
| Foxtail millet | 20.66 | 48.54 | 46.36 |
| Kodo millet | 13.63 | 15.32 | 15.22 |
| Mean | 0.67 | 1.24 | 1.43 |
| SEd | 0.314 | 0.258 | 1.252 |
| CD (P=0.05) | 0.669 | 0.551 | 2.670 |

The photosynthetic rate, transpiration rate and stomatal conductance of finger millet, little millet, barnyard millet, foxtail millet and kodo millet were observed at vegetative and flowering stages (Table 5). In general, a positive correlation exists between photosynthetic rate and other two parameters. In the present study also similar correlation was obtained among these parameters. The photosynthetic rate revealed significant differences among the small millets studied. The maximum photosynthetic rate (37.24 µmol $CO_2$ $m^{-2}$ $s^{-1}$), transpiration rate (11.34 mmol $H_2O$ $m^{-2}$ $s^{-1}$) and stomatal conductance (1.43 mol $H_2O$ $m^{-2}$ $s^{-1}$) was recorded at flowering stage in barnyard millet, which was followed by finger millet. Channappagoudar (2008a) reported that high yielding genotypes of barnyard millet had higher photosynthetic rates. Gollagi (2005) observed high stomatal conductance and moderate transpiration rate in high yielding genotypes of little millet. These findings are in accordance with the results of the present study. Udapudi *et al.* (1998) and Bhoite (2000) reported similar results in foxtail millet. But maximum leaf photosynthetic rates generally bear little relation to productivity under field conditions (Corley, 1983).

**Table 5. Gas exchange parameters of small millets at different growth stages**

| Crop | Vegetative | | | Flowering | | |
|---|---|---|---|---|---|---|
| | Photosynthetic rate (µmol $CO_2$ $m^{-2}$ $s^{-1}$) | Transpiration rate (mmol $H_2O$ $m^{-2}$ $s^{-1}$) | Stomatal conductance (mol $H_2O$ $m^{-2}$ $s^{-1}$) | Photosynthetic rate (µmol $CO_2$ $m^{-2}$ $s^{-1}$) | Transpiration rate (mmol $H_2O$ $m^{-2}$ $s^{-1}$) | Stomatal conductance (mol $H_2O$ $m^{-2}$ $s^{-1}$) |
| Finger millet | 30.21 | 6.34 | 0.32 | 35.54 | 10.34 | 1.41 |
| Little millet | 29.03 | 5.64 | 0.30 | 33.22 | 8.53 | 1.19 |
| Barnyard millet | 29.34 | 5.11 | 0.31 | 37.24 | 11.34 | 1.43 |
| Foxtail millet | 22.58 | 5.25 | 0.27 | 29.77 | 7.77 | 1.11 |
| Kodo millet | 24.56 | 5.50 | 0.29 | 29.89 | 8.28 | 1.16 |
| Mean | 27.14 | 5.56 | 0.29 | 33.13 | 9.25 | 1.26 |
| SEd | 0.385 | 0.072 | 0.006 | 0.572 | 0.085 | 0.011 |
| CD (P=0.05) | 0.820 | 0.154 | 0.012 | 1.220 | 0.182 | 0.024 |

**Table 6. Yield and yield components of small millets**

| Crop | No. of tillers $plant^{-1}$ | 100 grain wt (g $plant^{-1}$) | Grain yield (g $plant^{-1}$) | Harvest index |
|---|---|---|---|---|
| Finger millet | 12.6 | 0.39 | 28.92 | 0.39 |
| Little millet | 19.4 | 0.25 | 20.38 | 0.39 |
| Barnyard millet | 18.0 | 0.37 | 30.16 | 0.35 |
| Foxtail millet | 18.5 | 0.35 | 23.64 | 0.28 |
| Kodo millet | 16.5 | 0.32 | 18.70 | 0.48 |
| Mean | 17.0 | 0.34 | 26.76 | 0.37 |
| SEd | 0.22 | 0.007 | 0.40 | 0.004 |
| CD (P=0.05) | 0.43 | 0.015 | 0.86 | 0.010 |

Yield parameters were observed at maturity stage and recorded in Table 6. The highest 100 grain weight was observed in finger millet (0.39 g $plant^{-1}$) followed by barnyard millet (0.37 g $plant^{-1}$) and the lowest (0.25 g $plant^{-1}$) were observed in little millet. The effect of higher grain weight reflected on the grain yield of finger millet and barnyard millet. Harvest Index (HI) has positive relationship with seed yield. The HI of small millets ranged from 0.28 to 0.48. Kodo millet registered the highest HI of 0.48 followed by finger millet (0.39) and little millet (0.39). The lowest HI was observed in foxtail millet (0.28). The highest grain yield of 30.16 g $plant^{-1}$ was recorded by barnyard millet followed by finger millet (28.92 g $plant^{-1}$) and foxtail millet (23.64 g $plant^{-1}$).In the present study, the higher yield recorded in barnyard millet, finger millet and foxtail millet was attributed to the more number of tillers, photosynthetic rate and better partitioning to the developing grains, higher grain weight and LAI, LAD and total dry matter accumulation.

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