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Studies on Effect of Photosynthate Partitioning and Remobilization on Growth and Yield of Pearl Millet [*Pennisetum glaucum* (L.)] under Rainfed Condition

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Short Research Article

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ABSTRACT

The field experiment was conducted during *kharif*-2024 at Pearl Millet Research Station, JAU, Jamnagar to find out the "effect of photosynthate partitioning & remobilization on growth and yield of pearl millet under rainfed condition". The experiment was laid out in randomized block design with six selected hybrid and replicated thrice. To evaluate the effect of photosynthate partitioning and remobilization on the growth attributes, dry matter accumulation and yield performance of different pearl millet hybrids under rainfed condition. The selected hybrids were MPMH 17, MPMH 21, RHB 173, ABH 1200, Pusa composite 443 and Pusa composite 612 in the field under rainfed condition.

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The results showed that maximum plant height (166.67 cm) was recorded in AHB-1200 at maturity stage of the crop. The hybrid, AHB-1200 exhibited the maximum leaf dry weight (34.17 and 22.80 g), stem dry weight (54.90 and 177.70 g) and panical dry weight (20.97 and 109.33 g) at anthesis and maturity stage of the crop, respectively. The hybrid, AHB-1200 exhibited significantly highest grain yield (73.92 g/plant) and Harvest Index (23.84%).

Keywords: Pearl millet; hybrid; dry matter accumulation and grain yield.

1. INTRODUCTION

"Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is the most widely grown staple food of majority of poor and small land holders in Asia and Africa. It is also consumed as feed and fodder for livestock. It accounts for almost half of global millet production. It is the sixth most important cereal crop in the world next to maize, rice, wheat, barley and sorghum" (Maiti et al., 2016). "It occupies an area of 70.08 lakh hectares with an average production of 95.31 lakh tonnes and productivity of 1360 kg/ha in India during 2023-24" (Directorate of Economics and Statistics, 2024a). "The total area of pearl millet in the Gujarat state is 5.19 lakh hectares and production of 13.04 lakh tones with average productivity of 2511 kg/ha in 2023-24" (Directorate of Economics and Statistics, 2024b).

Pearl millet is recognized for its exceptional nutritional and health-promoting properties, making it particularly beneficial for individuals affected by lifestyle-related disorders such as diabetes and obesity (Ghatak et al., 2021). Compared to other staple cereals like wheat, rice, maize, and sorghum, it possesses a richer nutritional profile. The grain contains higher levels of fibre, minerals and bioactive compounds, which aid in maintaining healthy blood sugar levels, improving digestion, and supporting overall metabolic health" (Arya et al., 2022). "Pearl millet grain contains 9-15 per cent protein, 5-6 per cent carbohydrates and 1-2 per cent minerals and high densities of iron, zinc and more balanced amino acid profile and also rich in vitamins, thiamine and riboflavin content than maize and sorghum" (Chaudhari et al., 2018).

Pearl millet is an important cereal crop cultivated predominantly in the arid and semi-arid regions of Africa and the Indian subcontinent, where rainfall is limited, erratic, and poorly distributed. More than 90% of its global cultivation occurs under rain-fed conditions, making the crop highly vulnerable to intermittent and terminal drought stress during its growth cycle (Yadav et al., 2012). Despite these challenges, pearl millet is recognized for its exceptional resilience, largely attributed to its C_4 photosynthetic pathway, deep root system, and superior water-use efficiency (Kholováet al., 2010).

Under waterlimited environments, grain yield depends not only on current photosynthesis but also on the plant's ability to partition assimilates efficiently among vegetative and reproductive organs and toremobilize stored reservesduring grain filling (Blum, 1998). Photosynthate partitioning refers to the distribution of carbohydrates produced in the leaves to various sinks such as roots, stems and developing panicles. Rainfed conditions often reduce leaf expansion, chlorophyll content, and stomatal conductance, limiting carbon assimilation and altering the allocation of assimilates (Vadezet al., 2013). Consequently, the relative importance of stem and sheath carbohydrate reserves increases, especially when drought coincides with flowering or grain-filling phases. Remobilization of stored carbohydrates from stems and leaves to developing grains is a critical compensatory mechanism in cereals exposed to terminal drought (Bidinger et al., 1987). In pearl millet, stem reservesprimarily watersoluble carbohydrates (WSC) provide an alternative assimilate source when current photosynthesis fails to meet the demand of developing grains (Zhang et al., 2021). Genotypes capable of storing higher amounts of stem carbohydrates at anthesis and mobilizing them effectively to reproductive sinks show superior performance under rainfed stress, resulting in improved harvest index and grain yield stability (Srivastava et al., 2022).

Understanding the physiological basis of photosynthate partitioning and remobilization is therefore crucial for improving drought adaptation in pearl millet. With climate variability increasingly affecting rain-fed agriculture, identifying and exploiting genotypic differences in assimilate partitioning and stem reserve mobilization can support breeding strategies aimed at enhancing drought tolerance and ensuring yield security in marginal environments.

"At whole plant level, the canopy architecture, leaf morphological and vasculature architecture are the major traits that determine the photosynthetic capacity. At the cellular level, extensive cooperation between organelles involved in light perception, gene expression, biosynthesis of lipids, pigments, and proteins and expression of various transporters are required. Engineering the above developmental traits to improve photosynthetic efficiency, and thus yield, requires a thorough understanding of the physio logical basis of these traits. Considerable progress has been made to understand the above process in model species and major cereal crops. Photosynthesis related traits are one of the most important physiological factors responsible for plant productivity" (Evans, 2013).

2. MATERIALS AND METHODS

Field experiments on pearl millet different hybrid were conducted at Pearl Millet Research Station, Junagadh Agricultural University, Jamnagar during *kharif*season 2024. The soil of the experimental plot was clayey in texture, low in organic carbon (0.40 %), slightly alkaline in reaction with pH (8.50) and EC (0.47dS/m) in 2024, respectively. The soil was medium in available nitrogen, medium in available phosphorus and higher in available potash. The experiment was laid out in randomized block design with three replications and six selected hybrid were tested for studies on effect of photosynthate partitioning and remobilization on growth and yield of pearl millet under rainfed condition. The gross plot size was 5.0 m × 2.4 m (four row of five meters length) and net plot size was 4.0 × 1.2 m (two row of four meters length). All the recommended agronomical practices and plant protection measures were followed for raising a good crop. The observations *viz*., Plant height, leaves dry weight, stem dry weight, panicle dry weight, grain yield per plant, panicle harvest index and harvest index were recorded with tag ten similar plants, biomass sampling at anthesis (Record Plant height, leaves dry weight, stem dry weight, panicle dry weight separately of whole plant. 10 samples per treatment), biomass sampling at physiological maturity (Record Plant height, leaves dry weight, stem dry weight, panicle dry weight and grain separately of whole plant. 10 samples per treatment) and PNHI and HI calculate using following formula:

$$\text{Panicle Harvest Index} = \frac{\text{Grain yield (kg/ha)}}{\text{Dry ear head weight (kg/ha)}}$$

$$\text{Harvest Index} = \frac{\text{Economical yield (kg/ha)}}{\text{Biological yield (kg/ha)}}$$

3. RESULTS AND DISCUSSION

3.1 Plant Growth Attributes

Significant differences in plant height were observed among the different hybrids (Table 1). At the anthesis stage, the hybrid Pusa Composite-612 recorded the higher plants height (166.67cm) which was remained at par with AHB-1200. Whereas the maturity stage, AHB-1200 exhibited a significantly increase plant height (185.07cm), which was statistically comparable with Pusa Composite-612 and Pusa Composite-443.Increased plant height is generally associated with greater vegetative vigor and photosynthetic surface, which facilitates higher carbohydrate production and subsequent translocation to reproductive, sinks (Ausiku et al., 2022, Bidinger et al., 2006). Under rainfed conditions, plant height is often indicative of genotypic adaptability to moisture stress (Choudhury et al., 2022).

3.2 Dry Matter Accumulation and Partitioning

Dry matter accumulation in leaves and stems varied significantly among the evaluated hybrids (Tables 1–2). AHB-1200 produced the highest leaf dry weight at both anthesis (34.17 g) and maturity (22.80 g), which was statistically at par with MPMH-17 at the anthesis stage. Stem dry weight was also significantly superior in AHB-1200 (54.90g and 177.70g) at anthesis and maturity stage, remaining comparable with Pusa Composite-443, Pusa Composite-612 and RHB-173 at anthesis and with Pusa Composite-443 at maturity. Increased vegetative biomass around flowering has been widely associated with enhanced photosynthetic capacity and sustained assimilate supply during grain filling under limited moisture (Sithole et al*.,* 2025 and Kapoor et al., 2022). Recent studies in pearl millet report that hybrids with higher stem and leaf biomass tend to exhibit superior assimilate partitioning, improved remobilization efficiency and better grain development under rainfed and heat-stress environments (Govindaraj et al., 2010 and Singh et al., 1987). Enhanced stem reserve mobilization, particularly during post-anthesis stress, has been highlighted as a crucial adaptive mechanism buffering grain filling and stabilizing yield under terminal drought (Kholová et al., 2016; Vadez et al., 2017).

Panicle dry weight was found significantly higher in AHB-1200 (20.97g and109.33g) at anthesis and maturity stage, which remained statistically at par with Pusa Composite-443 at the respective maturity stages. This clearly indicates its superior source capacity and efficient partitioning ability. Effective partitioning of assimilates to developing panicles is critical for yield improvement, particularly under moisture stress where photosynthate remobilization plays a vital compensatory role (Bidinger et al., 2005). The high panicle dry weight recorded in AHB-1200 reflects its greater sink strength and better conversion of structural biomass into productive biomass.

3.3 Photosynthate Remobilization and Harvest Index

Significant differences were observed among the hybrids with respect to grain yield per pant and harvest index (Table 2). The hybrid AHB-1200 also produced a significantly highest grain yield (73.92 g plant^{-1}) among the different hybrids. Grain yield in pearl millet varies widely among hybrids due to differences in assimilate production, partitioning efficiency, and stress tolerance. Hybrids generally outperform open-pollinated varieties because of their superior biomass and stronger sink capacity (Yadav et al., 2012). Yield is closely associated with traits such as panicle size, grain number, and harvest index, as well as efficient remobilization of stored assimilates during grain filling (Kapoor et al., 2022). Under rainfed conditions, hybrids with better water-use efficiency and sustained photosynthesis tend to achieve higher yields (Directorate of Agriculture, 2024b, Kholováet al., 2010).

The higher harvest index (23.84%) was recorded with MPMH-21, which remained statistically at par with MPMH-17, RHB-173, and AHB-1200. No significant differences were observed among the hybrids with respect to panicle harvest index.

Table 1. Evaluation of entries for plant growth attributes and dry Matter accumulation in pearl millet under rain-fed condition

No	Name of variety	Plant Height (cm)		Leaf dry wt. (g)		Stem dry wt. (g)	
		anthesis stage	maturity stage	anthesis stage	maturity stage	anthesis stage	maturity stage
1	MPMH-17	128.67	150.40	27.00	16.27	33.40	99.27
2	MPMH-21	122.50	137.30	21.17	13.57	30.20	86.87
3	RHB-173	127.83	143.77	16.43	14.57	42.47	96.17
4	AHB-1200	156.67	185.07	34.17	22.80	54.90	177.70
5	Pusa comp-443	153.83	167.93	19.13	15.23	51.47	159.83
6	Pusa comp-612	166.67	182.30	20.17	13.97	46.73	152.93
	SEm±	3.85	7.06	2.94	2.73	5.22	7.63
	C.D. 5%	12.12	22.24	9.26	NS	16.45	24.05
	C.V. %	4.67	7.59	22.11	29.45	20.93	10.26

Table 2. Evaluation of entries for photosynthate remobilization and harvest index in pearl millet under rain-fed condition

No	Name of variety	Panicle dry wt. (g)		Grain yield (g/plant)	Penicle Harvest index (%)	Harvest Index (%)
		Anthesis stage	Maturity stage			
1	MPMH-17	16.57	87.33	55.95	63.94	27.51
2	MPMH-21	13.43	77.73	50.93	66.60	28.61
3	RHB-173	15.53	82.83	52.57	63.19	27.15
4	AHB-1200	20.97	109.33	73.92	67.51	23.84
5	Pusa comp-443	17.73	91.50	56.52	63.35	21.33
6	Pusa comp-612	16.70	70.00	45.42	64.89	19.22
	SEm±	1.71	6.44	5.17	5.52	2.03
	C.D. 5%	NS	20.29	16.28	NS	6.40
	C.V. %	17.64	12.90	16.02	14.72	14.29

A high harvest index in cereals indicates efficient translocation of photosynthates from vegetative tissues to developing grains (Reynolds et al., 2009). Under terminal stress conditions common in rainfed pearl millet -remobilization of pre - anthesis reserves becomes a key determinant of grain filling (Shearman et al., 2005, Wardlaw, 1990).

4. CONCLUSION

The hybrid AHB-1200 showed superior morphological growth, greater dry matter accumulation and more efficient partitioning and remobilization of assimilates, along with the highest grain yield and harvest index under rainfed conditions. These traits indicate that AHB-1200 is a physiologically efficient, high-yielding hybrid well suited for moisture-limited semiarid regions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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