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UNDERSTANDING *AVENA SATIVA* RESILIENCE UNDER MOISTURE STRESS BY EXPLORING MORPHO-PHYSIOLOGICAL AND BIOCHEMICAL PARAMETERS

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SUMMARY

Water scarcity is a major agricultural threat, impacting diverse crops like oats. To understand the mechanism that how oats cope with moisture stress at the morpho-physiological level is crucial for developing resilient cultivars and adapting agricultural practices. This study aimed to evaluate the morpho-physiological parameters of 14 *Avena sativa* (oat) varieties (OS 7, OS 346, OS 377, OS 403, OS 405, OS 424, OS 427, HFO 529, HJ 8, HFO 114, HFO 611, HFO 607, HFO 707 and HFO 906) under varying levels of moisture stress. Different oats varieties were subjected to four different levels of moisture saturation (100, 75, 50 and 25%). Parameters studied were shoot and root length, fresh weight (FW) and dry weight (DW) of shoot and root, anthocyanin, flavonoids, chlorophyll index and nitrogen balance index (NBI). Based on two-year study, significant variation was observed among the 14 oat varieties under moisture stress conditions. Among varieties HFO 611, HJ-8, OS 424 and OS 377 were found promising on the basis of better morpho- physiological performance (higher value of dry weight of shoot and root, chlorophyll index, nitrogen balance index, anthocyanin) under moisture stress conditions.

Key words: Oat, moisture stress, drought tolerance, chlorophyll, anthocyanin

Water scarcity hinders crop yields by limiting their ability to reach their full genetic potential. It poses a significant threat, impacting growth and leading to stunting, wilting, discoloration, and yellowing of leaves (Yadav *et al.,* 2022). Notably, young plants are particularly vulnerable to water scarcity due to their underdeveloped resistanc. Drought can inhibit or delay seed germination and hinder the establishment of a healthy crop stand (Kumar *et al*., 2012). Furthermore, it reduces shoot and root length, fresh and dry weight of shoot and root. The stress of drought extends beyond visual effects, causing damage to photosynthetic organs, altering cell structure and function, disrupting metabolic processes, and hindering nutrient absorption and transport (Farooqi *et al*., 2020; Bashir *et al*., 2021). Abiotic stress triggers an increase in flavonoids and anthocyanins, while decreasing chlorophyll index (Devi *et al*., 2020). Drought stress further complicates matters by decreasing the Nitrogen Balance Index (NBI), a crucial indicator of plant nitrogen content. This index, calculated as the ratio of chlorophyll (Chl) to epidermal flavonoids (Flav), reveals a decline in plant nitrogen when under water stress. To improve drought tolerance, researchers can explore and harness the natural variation in physiological traits present in different crop varieties (Sharma *et al*., 2023). Changes in climate significantly impact the performance of different genotypes, making the selection of varieties that thrive under water stress crucial for enhancing agriculture (Kapoor *et al*., 2020). Breeding efforts for drought tolerance aim to develop cultivars that maintain high yields even under water-limited conditions, with the assumption that these varieties will also offer yield advantages in less than ideal environments. Rosero *et al*. (2020) proposed selecting and incorporating specific physiological traits into new cultivars through traditional breeding methods to create varieties specifically adapted to water-scarce environments. However, many breeding programs focus on a limited number of drought-tolerant characteristics, hoping they will translate to yield benefits under water stress.

Oat (*Avena sativa* L.) is an important annual crop produced on a global scale as human food and animal feed (Devi *et al*., 2019). Its grain is renowned as a rich source of dietary fiber, such as soluble fiber β-glucan, as well as being high in antioxidants, minerals, and vitamins. It is a superior species to solve the problem of foraging during the cold season. Oats rank around sixth in the world cereal production statistics following wheat, maize rice, barley and sorghum (Devi *et al*., 2021). Oats are better adapted to variable soil types and can perform better on acid soils than other small grain cereals crops. They are mostly grown in cool moist climates and they can be sensitive to hot, dry weather from head emergence through to maturity (Bibi *et al*., 2022). A wide range of chemical constituents like carbohydrates, proteins, avenanthramides, tocols, lipids, alkaloids, flavonoids, saponins, and sterols have been reported from *A. sativa*. Traditionally oats have been in use since long and are considered as stimulant, antispasmodic, antitumor, diuretic, and neurotonic. Oat possesses different pharmacological activities like antioxidant, anti-inflammatory, wound healing, immunomodulatory, antidiabetic, anticholesterolaemic, etc. A wide spectrum of biological activities indicates that oat is a potential therapeutic agent. The seedling stage is the key period for oat growth and development. Therefore, it is of great significance to study the effects of early spring drought on oat growth and the adaptive mechanism of oats to drought for the selection of drought-resistant varieties. Little information is available on the response of oats (*Avena sativa* L.) to periodic water deficits experienced at different growth stages. Knowledge conceming the manner in which oats responds to water stress is needed to aid in water management of the crop.

The primary objective of this study was to determine the effect of water stress imposed upon the growth components and nonenzymatic antioxidants of oat.

MATERIALS AND METHODS

Fourteen oat varieties (OS 7, OS 346, OS 377, OS 403, OS 405, OS 424, OS 427, HFO 529, HJ 8, HFO 114, HFO 611, HFO 607, HFO 707 and HFO 906) were procured from the Forage Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar, to conduct the experiment using the sand culture method. The substrate was prepared as a 3:1 mixture of fine sand and vermiculite. Uniform, disease-free oat seeds were sterilized with 1% sodium hypochlorite for 10 minutes, rinsed five times with distilled water, and sown in basins of 10 cm diameter and 15 cm height. The experiment was carried out during the rabi seasons of 2021–22 and 2022–23 in the Screen House of the Department of Botany and Plant Physiology, CCS Haryana Agricultural University, Hisar. Four moisture saturation levels (100%, 75%, 50%, and 25%) were maintained and 500 ml of Hoagland solution was applied every two days after seed emergence. Observations on shoot and root length, fresh and dry weights of shoot and root, anthocyanin, flavonoids, chlorophyll index, and nitrogen balance index (NBI) were recorded at 30 and 60 days after sowing in a completely randomized design (CRD). Shoot length was measured from the soil surface to the shoot tip using a meter scale, while root length was determined by carefully removing plants from the substrate, washing roots with tap water, and measuring their length using a meter scale. Fresh weights of shoots and roots were recorded by washing, pat-drying, and weighing the samples on an electronic balance. Dry weights were measured after drying the samples in an oven at 60°C for 72 hours. Chlorophyll, flavonoids, anthocyanin, and NBI were measured non-destructively using a polyphenol chlorophyll meter (Dualex Scientific, Force A, Orsay, France) on the third fully expanded leaf of each plant. Statistical analysis was conducted using a two-factor CRD. Treatments were compared using the critical difference (CD) at a 5% significance level, with data analyzed using the Online Statistical Analysis Package (OPSTAT) from CCS Haryana Agricultural University, Hisar.

RESULTS AND DISCUSSION

Limited water availability directly hinders cell expansion and division, the fundamental building blocks of plant growth. Additionally, drought triggers hormonal imbalances, favoring stress hormones that inhibit growth and diverting energy towards survival mechanisms instead. This complex interplay of water scarcity, hormonal shifts, and resource allocation ultimately leads to the observed stunting of both roots and shoots under drought stress (Naeem and Selamoglu, 2022). In this study, Length of shoot and root of oat varieties varied with different moisture stress at 30 and 60 DAS [Fig. 1 (a and b) and 2 (a and b)]. Length of shoot and root decreased with the imposition of moisture stress (100-25%) and the values varied from 33.0 to 24.0 cm at 30 DAS and 37.8 to 27.5 cm at 60 DAS. Shahzad *et al*. (2023) also reported similar decline in wheat and maize respectively. The differential performance of fodder oat genotypes could be ascribed to their genetic makeup also (Satpal *et al*., 2018 and Satpal *et al*., 2024).

When drought strikes, plants face a water shortage, impacting both their roots and shoots. Roots

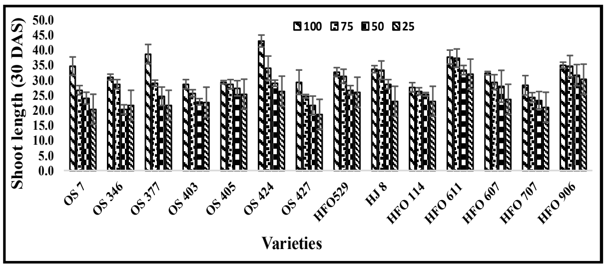

Fig. 1a. Shoot length of oat varieties as influenced by different moisture levels at 30 DAS.

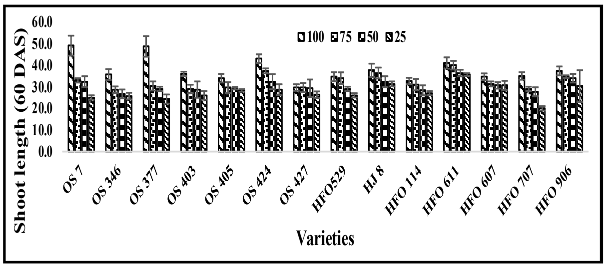

Fig. 1b. Shoot length of oat varieties as influenced by different moisture levels at 60 DAS.

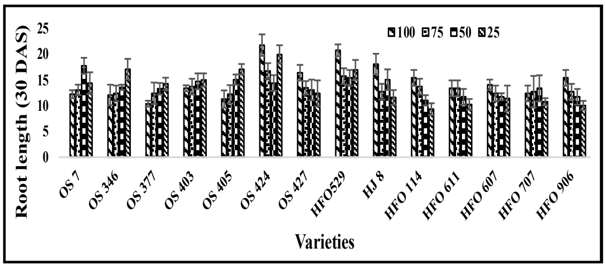

Fig. 2a. Root length of oat varieties as influenced by different moisture levels at 30 DAS.

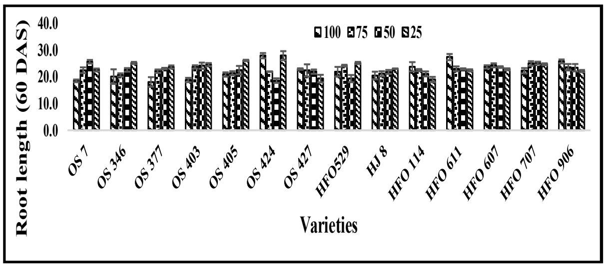

Fig. 2b. Root length of oat varieties as influenced by different moisture levels at 60 DAS.

struggle to absorb water and nutrients, hindering the supply of essential resources to the shoots. Meanwhile, shoots prioritize water conservation by reducing growth and shedding leaves, leading to a decline in fresh weight (Soliman *et al*. 2022). In our study fresh weight of shoot and root showed declining trend with the increment of moisture stress i.e. 1.37-0.20 and 1.60-0.46 g (Fig. 3), 0.253-0.093 and 0.304-0.128 g (Fig. 4). We also reported reduction in dry weight from 0.184-0.065 and 0.230-0.085 g (Figs. 5 and 6) respectively, at 30 and 60 DAS respectively, from 100 to 25% saturation of moisture stress. Mishra and

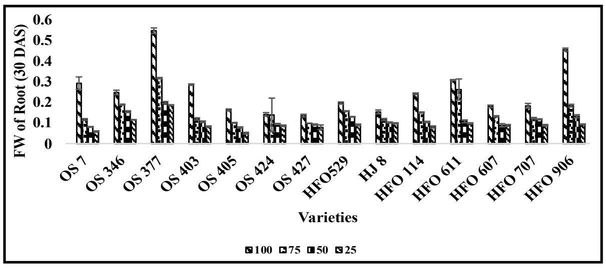

Fig. 3a. Fresh weight (FW) of root of oat varieties as influenced by different moisture levels at 30 DAS.

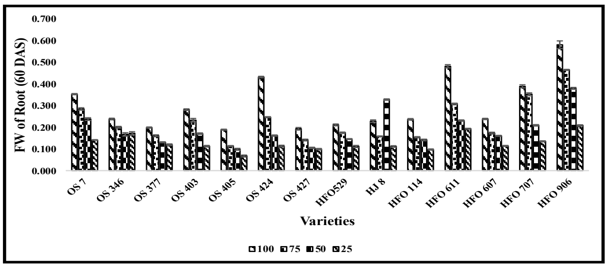

Fig. 3b. Fresh weight (FW) of root of oat varieties as influenced by different moisture levels at 60 DAS.

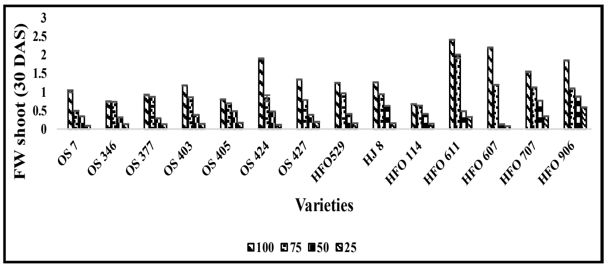

Fig. 4a. Fresh weight (FW) of shoot of oat varieties as influenced by different moisture levels at 30 DAS.

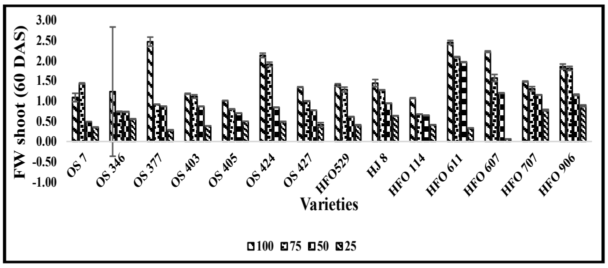

Fig. 4b. Fresh weight (FW) of shoot of oat varieties as influenced by different moisture levels at 60 DAS.

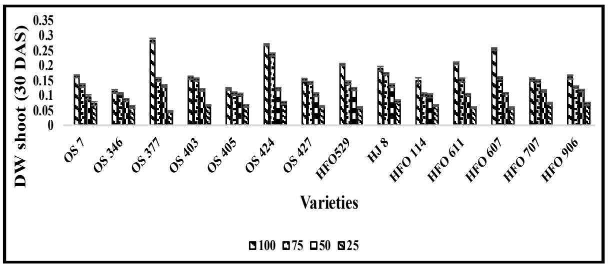

Fig. 5a. Dry weight (DW) of shoot of oat varieties as influenced by different moisture levels at 30 DAS.

Patidar (2023) also noted decline in root -shoot fresh weight in soybean under drought stress.

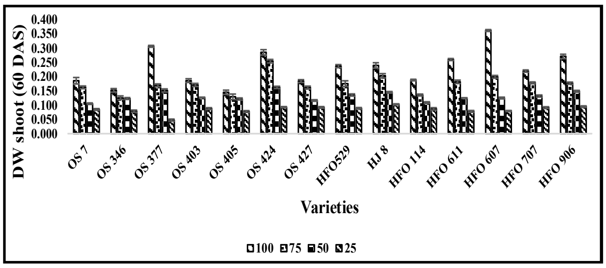

Fig. 5b. Dry weight (DW) of shoot of oat varieties as influenced by different moisture levels at 60 DAS.

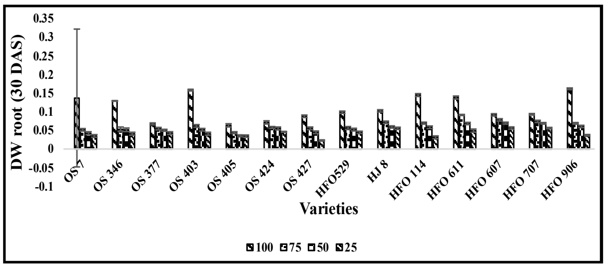

Fig. 6a. Dry weight (DW) of root of oat varieties as influenced by different moisture levels at 30 DAS.

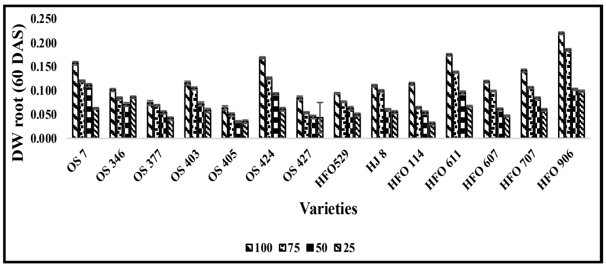

Fig. 6b. Dry weight (DW) of root of oat varieties as influenced by different moisture levels at 60 DAS.

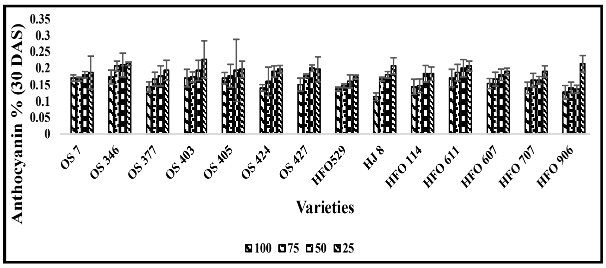

Fig. 7a. Anthocyanin of oat varieties as influenced by different moisture levels at 30 DAS.

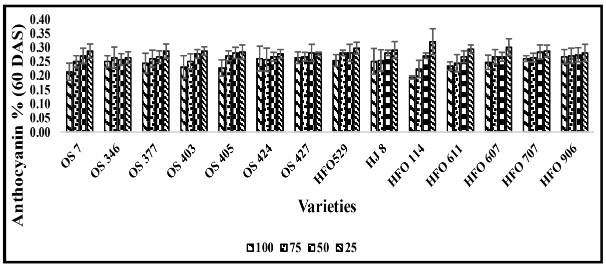

Fig. 7b. Anthocyanin of oat varieties as influenced by different moisture levels at 30 DAS.

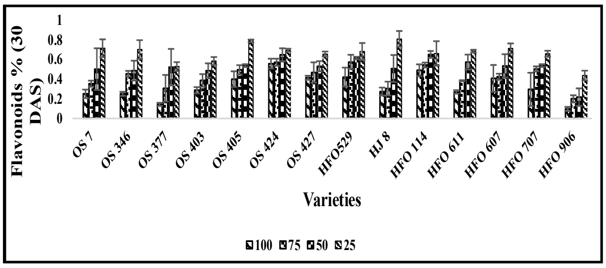

Fig. 8a. Flavonoids of oat varieties as influenced by different moisture levels at 30 DAS.

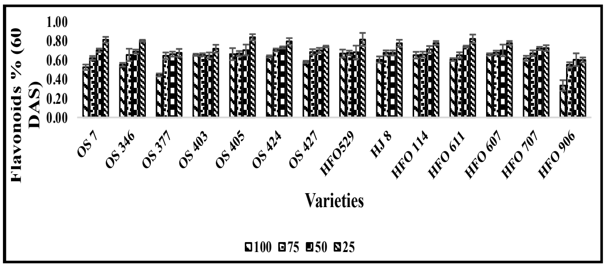

Fig. 8b. Flavonoids of oat varieties as influenced by different moisture levels at 60 DAS.

When plants face drought stress, they ramp up production of anthocyanins and flavonoids as a multi-pronged defense mechanism. These antioxidant pigments act like shields, scavenging free radicals generated by water scarcity. Additionally, they stabilize cell membranes, attract helpful microbes, and signal to neighboring cells about the stress, all contributing to the plant's resilience and survival during dry spells. In results, Fig. 7 (a and b) and 8 (a and b) represents the anthocyanin and flavonoids content that increased with the increment of moisture stress at both stages (30 and 60 DAS), Anthocyanin found on higher side in oat variety OS 403 (0.23) indicating its role in stress protection. Flavonoid content was significantly different between genotypes, with OS 405 exhibiting higher levels (0.79 and 0.72) at 25% of moisture stress at 30 and 60 DAS. Flavonoids increased with moisture stress but the increment was slightly lower at 60 DAS at 25% of moisture as compared to 30 DAS. Results are in correlation with Chen *et al.* (2022) in *Brassica napus*.

Without enough water, the plant can't efficiently synthesize the building blocks of chlorophyll, while the harsh environment damages and degrades the existing chlorophyll molecules. Drought makes it harder for plants to absorb and utilize nitrogen, a key element for chlorophyll synthesis and protein building. This nitrogen deficiency further hinders chlorophyll production and disrupts the delicate balance between nitrogen uptake and loss, reflected in a declining NBI (Liu *et al.* 2024). Our results showed that increasing levels of moisture stress led to a decline in chlorophyll index and nitrogen balance index (NBI) in oat genotypes (Fig. 9 and 10). Moisture stress significantly decrease the chlorophyll index from 24.2

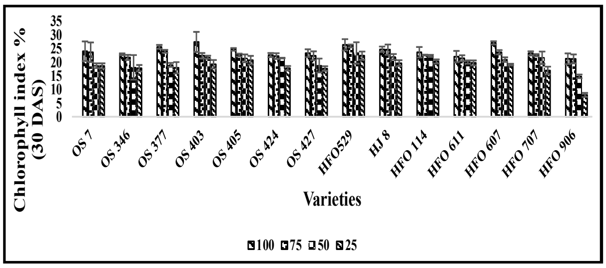

Fig. 9a. Chlorophyll index of oat varieties as influenced by different moisture levels at 30 DAS.

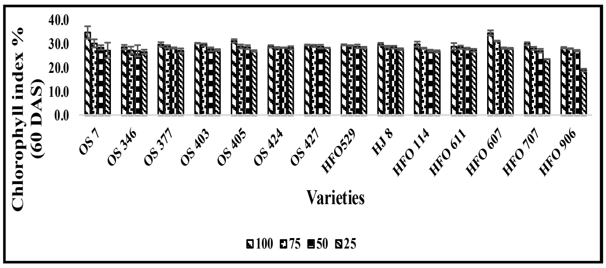

Fig. 9b. Chlorophyll index of oat varieties as influenced by different moisture levels at 60 DAS.

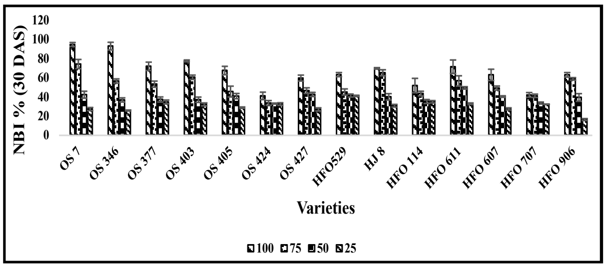

Fig. 10a. Nitrogen balance index (NBI) of oat varieties as influenced by different moisture levels at 30 DAS.

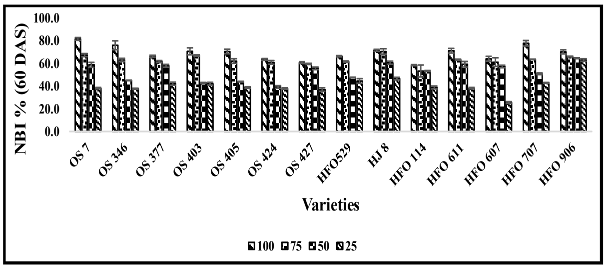

Fig. 10b. Nitrogen balance index (NBI) of oat varieties as influenced by different moisture levels at 60 DAS.

to 18.2 and 30.4 to 26.7 at 30 and 60 DAS with the onset of moisture stress (100 to 25%). The NBI showed a decline from 66.2 to 30.2 and 69.3 to 41.0 at 30 and 60 DAS under moisture stress, indicating a nitrogen deficiency that affects chlorophyll synthesis. Similar results on chlorophyll content and NBI were recorded by Liu *et al.* (2024) in tomato.

CONCLUSION

Oat varieties HFO 611, HJ-8, OS 424, and OS 377 demonstrated superior performance under drought stress at both 30 and 60 days after sowing (DAS). This highlights the potential of using growth parameters, non-enzymatic antioxidant levels, nitrogen balance index (NBI), and chlorophyll content as effective markers for screening drought resistance in oat varieties. Notably, oats responded to drought stress by increasing non-enzymatic antioxidant activity, contributing to their resilience. Furthermore, root shoot length, root shoot fresh and dry weight and chlorophyll content emerged as key attributes for evaluating drought resistance in oats. Given their superior performance, HFO 611, HJ-8, OS 424, and OS 377 stand out as promising candidate materials for breeding programs aimed at developing drought-resistant oat cultivars. Their use as control parents in cross-breeding programs can hold significant potential for advancing the genetic improvement of oats and ensuring their adaptability to drier conditions.

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