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Management Strategies of Pearl Millet [*Pennisetum glaucum* (L.) R. Br.] to Cope with Rainfall Anomalies under Semi-Arid Regions of Rajasthan

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Abstract: Field experiment was carried out at Rajasthan Agricultural Research Institute, Durgapura, Jaipur, during *kharif* seasons of 2019 and 2020 to optimize pearl millet production in the face of rainfall irregularities. The experiment comprises two pearl millet varieties (RHB-173 and RHB-177), four transplanting shock preventing methods (No treatment, Triacontanol @ 0.25 ml/litre, Triacontanol @ 0.50 ml/litre and Leaf clipping) and three transplanting dates (15^{th}-30^{th} June, 1^{st}-15^{th} July and 16^{th}-31^{st} July). Pearl millet cultivar RHB-173 observed significant effect on growth and yield of pearl millet as compared to RHB-177. Among the transplanting shock preventing methods, triacontanol @ 0.25 ml/litre found better effect on growth and yield of pearl millet as compared to no treatment, triacontanol @ 0.50 ml/litre and leaf clipping. The appropriate date for pearl millet transplanting was noted1^{st}-15^{th} July to encouraging growth and yield of pearl millet in contrast to 15^{th}-30^{th} June and 16^{th}-31^{st} July. The study indicated the pearl millet variety RHB-173 transplanted during 1^{st}-5^{th} July with seedling treatment triacontanol @ 0.25 ml/litre a promising strategy for improving pearl millet production.

Keywords: Growth, Pearl millet, Transplanting, Transplanting shock, Variety, Yield

Pearl millet is a main coarse grain grown as a rainfed crop on marginal soils with minimal input management and holds a prominent position in dryland agriculture and makes a substantial contribution to the food security of the nation due to its innate ability to escape drought and adaption to drier and lessfertile conditions (Kumar et al 2024). The rainfall pattern of Rajasthan is extremely irregular and varies greatly from area to area as well as from year to year (Pingale et al 2014). It directly influences the agricultural practices, particularly planting date, which significantly affects crop production (Nwajei et al 2019).The regional rainfall data of the last few years reveals that the monsoon rain does not occur at traditional dates of onset, an increase in the frequency of heavy rains in one day (Mukherjee et al 2018), shifting of the peaks of monsoon rains towards July and an increase in pre-monsoon (May-June) rains (Deoli and Rana 2019). Kumar et al (2010) found a decrease in annual and monsoon rainfall while increasing in winter, pre and post-monsoon seasons across India.

The production season of pearl millet is generally from late May to September. However, acreage, production and productivity are solely determined by the occurrence of the monsoon and delayed monsoon does not leave scope for its significant cultivation as the crop is bound to suffer from terminal drought. If the rains fail or end early, farmers could need to re-sow, this can be risky as the season may not be long enough for the crop to reach maturity, and the harvests may be small or even fail. Postponements in the pearl millet sowing reduce grain yield significantly, the rate of decline ranged from 4-80 kg/day/ha under dryland conditions Framers can't afford to sacrifice pearl millet as substitute crops do not provide sufficient fodder for livestock under the traditional system of mixed farming. Therefore, raising an advanced nursery of prominent varieties and transplanting them at a suitable time alleviate the problem of patchy stands and replanting costs, this reduces the growing period in the field, thus providing an earlier harvest, ease up the problem of short-duration rainfall and providing an additional dimension to food security. Transplanting is a conventional approach in certain regions of Africa and Asia in pearl millet and sorghum cultivation; moreover to fill gaps after crops emerge and thinning or to compensate for a growth period that is too short for an entire crop cycle (Khairwal et al 1990, Oswald et al 2001). The benefits of this practice are better control of crop density and higher yields (Tinh et al 1993). Transplanting of seedlings increases the yield and conjointly compensates the yield losses due to delay sowing (Upadhyay et al 2001, Jan et al 2015).

Imposing transplanting time on a crop is one of the good agronomic options to sustain crop production. Timely planting of crops typically ensures ample time for root development and vegetative growth for optimum harvesting of available soil nutrients and radiant energy (Akhtar et al 2007). The variations in phenology, growth andyield were observed due to alterations in planting time andgenotype variability under arid and semi-arid environments (Soler et al 2008).Transplanting damages seedling roots, causing in an imbalance between water absorption and transpiration. Consequently, the growth and development of seedlings temporarily stagnate. This phenomenon is termed as transplant shock. The extent and duration of transplant-shock injuries have an effect on crop growth and yield. Triacontanol produces stronger seedlings with a far better root system and eventually develops into vigorous plants that produce better yields and conjointly increases the rates of several biochemical and physiological processes (Naeem et al 2010). Clipping of leaves has alternative choices at transplantation, allowing the seedlings to recover from transplanting shock quicker than the non-clipped ones. Leaf clipping at transplanting does not immediately improve plant water status, but it may alleviate drought stress. It conjointly been reported that leaf clipping presumably removes transpiring biomass and conserves soil moisture.

Another most important criterion is introducing an appropriate high-yielding cultivar with an appropriate maturity duration that matches into a specific water availability period not solely minimizes the risks but also ends up in a net yield enhancement. Cultivars have been reported to behave differently with transplanting (Ullah et al 2017). Traditional varieties are generally considered to have low productivity when compared to high yielding varieties and hybrids, thus they are often neglected and even avoided in the mainstream of pearl millet production. Hence, there is an extensive need to screen out such kinds of cultivars which not only have the potential to increase yield but conjointly appropriate for transplanting.

MATERIAL AND METHODS

Experimental site and location: The experiment was conducted at Rajasthan Agricultural Research Institute, Durgapura, Jaipur (Rajasthan) during *kharif* seasons 2019 and 2020, respectively. Geographically this place is situated at 26°51' North latitude, 75°47' East longitudes and at altitudes of 390 m above mean sea level in Jaipur district of Rajasthan and region falls under Agro-climatic zone III-a (Semi-arid eastern plain zone) of Rajasthan.

Climate and weather conditions: The climate of this region is a typically semi-arid and experiences extremes of temperature during both in summers and winters. The average annual rainfall of this tract varies from 400 mm to 500 mm and 85 to 91%is received from June to September (*kharif* season) by the south west monsoon. The periodical mean weekly weather parameters during both the years of experimentation recorded from the meteorological observatory of Rajasthan Agricultural Research Institute, Durgapura, Jaipur (Fig. 1, 2). The mean daily maximum and minimum temperature fluctuated between 31 to 44.6°C and 21.6 to 30.1°C, and 30.4 to 40.9°C and 20 to 28.3°C during the crop growing seasons 2019 and 2020, respectively. There was rainfall of 748.2 mm and 518.6 mm during the 2019 and 2020, respectively during both the seasons. The evaporation data revealed that the weekly average evaporation varied from 14.2 to 1.7 and 10.3 to 2.5 mm/day during experimental seasons 2019 and 2020, respectively. The entire weather data indicated that the weather conditions were normal and favourable for the adequate growth and development of the pearl millet crop during the both *kharif* seasons of 2019 and 2020.

Treatments: The experiment comprises two pearl millet varieties *viz*., V_1- RHB-173 and V_2- RHB-177), four transplanting shock preventing methods *viz*., M_0- No treatment, M_1- Triacontanol @ 0.25 ml/litre, M_2- Triacontanol @ 0.50 ml/litre and M_3- Leaf clipping) and three dates of transplanting *viz*., D_1- 15th-30th June, D_2- 1st-5th July and D_3- 16th-31st July) replicated thrice in factorial randomized block design.

RESULT AND DISCUSSION

Growth Parameters and Grain Yield of Pearl Millet

Effect of varieties: The growth attributes *viz.* plant height, dry matter accumulation, number of tillers per plant, leaf area and grain yield of pearl millet, exhibited marked differences due to the varieties.Initially (20 DAT), both the pearl millet varieties did not vary significantly in their plant height and dry matter accumulation but at 40 DAT and at harvest, hybrid RHB-173 observed significantly taller plant and greater biomass as compared to RHB-177. The pearl millet variety RHB-173 also recorded significantly higher number of tillers per plant and maximum leaf area over RHB-177 at 20 and 40 DAT and at harvest. The improvement in these growth attributes might be due to more penetration of solar radiation and the hybrids have the inherent ability to utilize solar radiation efficiently owing to their larger photosynthetic area, which probably accounts for more photosynthesis to produce a higher number of tillers per plant, resulting in a greater accumulation of dry matter (Gupta et al 2016). The differences in the overall growth, development and grain yield of pearl millet varieties are mainly due to variation in their genetic make-up, weather conditions and agronomical assist supplied during the life cycle. The genetic potential of cultivar RHB-173 permitted the transformation of higher energy into the formation of a number of yield determining traits shown to be profitable in improving the grain yield of pearl millet. Similar kinds of results were also reported by earlier scientists (Sharma et al 2013, Yadav et al 2014, Ullah et al 2017).

Effect of transplanting shock preventing methods: The growth parameter *i.e.* plant height, number of tillers, leaf area, and dry matter production observed at 20 days periodic intervals up to harvest and grain yield showed a significant improvement due to transplanting shock preventing methods over no treatment during both the years of study and on the basis of pooled analysis.The different doses of triacontanol *i.e.* 0.25 and 0.50 ml/litre remained at par with each other to improve these growth attributes and grain yield, but above both doses proved significantly superior over leaf clipping and no treatment at all the crop growth stages at 20, 40 DAT and at harvest. Triacontanol, being a plant growth promoter, stimulates plant growth and the rate of several biochemical and physiological processes of various crops (Naeem et al 2010). Triacontanol alleviates the adverse effect of transplanting shock on crop growth during the recovery stage

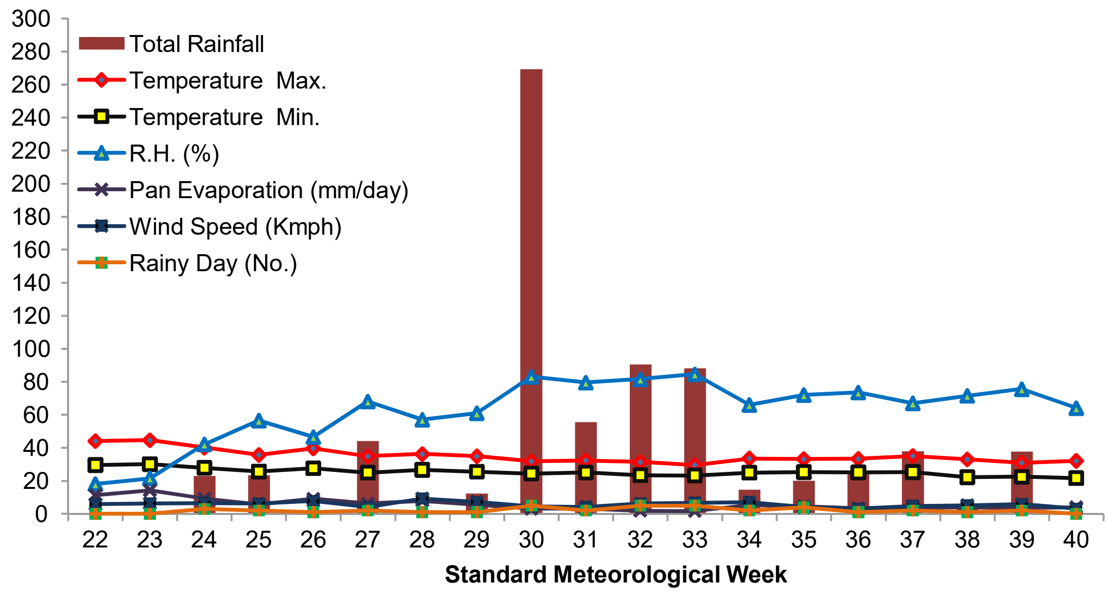

Fig. 1. Mean weekly meteorological data during crop season (*Kharif,* 2019)

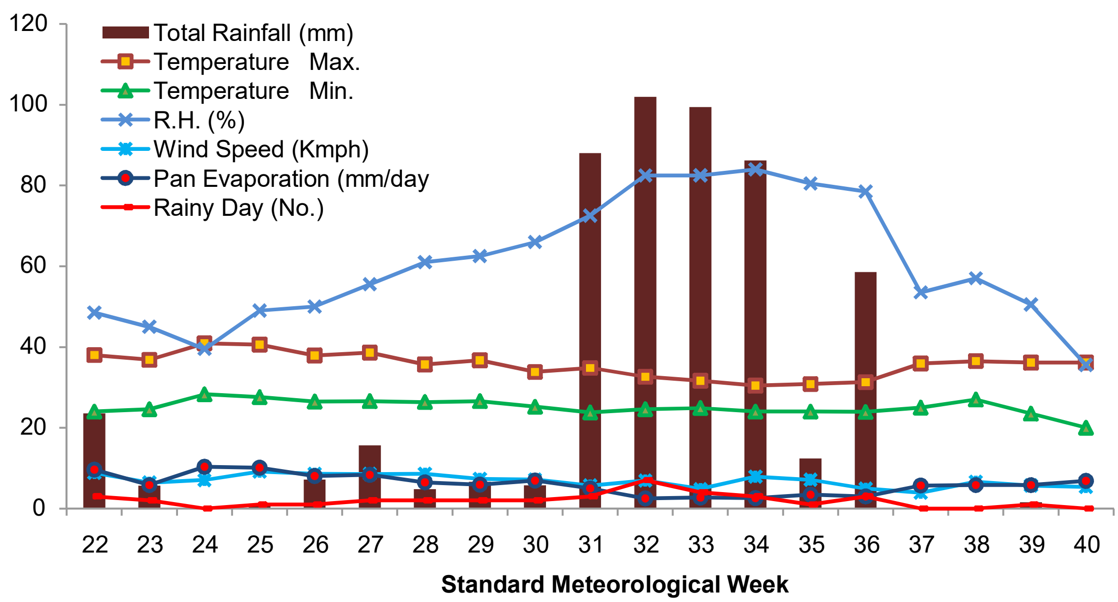

Fig. 2. Mean weekly meteorological data during crop season (*Kharif,* 2020)

of pear millet seedlings after transplanting. The increment in all growth parameters might be due to the synthesis of a higher amount of chlorophyll content and increased photosynthetic activity, CO_2 fixation rate, and greater translocation of photosynthates from sink to source. In addition to this, triacontanol increases water and nutrient uptake, which might be due to better development of roots, rapid cell division and cell elongation resulting in enhanced growth and development of the plant. Triacontanol alleviates transplanting shock and shortens the recovery period by regulating antioxidant enzymes and the redox states of ASA and GSH, resulting in less ROS damage due to increased photosynthetic efficiency with greater translocation of photosynthates towards the reproductive system and accumulation in the sink, and, ultimately, increased grain and stover yield (Li et al 2016, Khardia et al 2020). Leaf clipping at transplanting also promoted all the growth attributes as compared to no treatment during years of investigation. This might be due to removal of transpiring biomass from seedlings at transplanting helped to rapid recovery from transplanting shock and the crop's better withstand under water stress conditions as transpiration was checked through clipping of leaves, which resulted in the well establishment of seedlings and it leads to faster growth and development of plants and, ultimately increased grain yield of pearl millet in comparison to non-clipped transplants. These results are in close conformity with the findings of Mapfumo et al (2007) in pearl millet and sorghum.

Effect of transplanting dates: The different transplanting dates revealed a significant influence on growth parameters such as plant height, dry matter accumulation, total tillers per plant, and leaf area at various physiological growth stages, as well as grain yield of pearl millet. The second date of transplanting (1^{st}-15^{th} July) had taller plants, higher biomass accumulation, a greater number of tillers, more leaf area, and grain yield than the first date of transplanting (15^{th}-30^{th} June), but the later date of transplanting had a similar growth pattern (16^{th}-31^{st} July). This could be because timely planting provides favourable climatic conditions, such as temperature, soil moisture, and longer sunshine hours, which stimulate the plants to increase their growth and development in comparison to early planting, resulting in higher grain yield. In contrast, all of these parameters were reversed in the early transplanted crop, resulting in lower values of these growth contributing traits and grain yield of pearl millet. This may be due to an unexpected moisture deficiency and high temperature during the initial crop growth stage, which hampered crop establishment. Comparable results were reported by Siddig et al (2013), Ullah et al (*2017*) and Londhe et al (2020).

Regression analysis: The regression equation predicted linear increment in the grain yield with a unit increase in the

Table 1. Effect of transplanting dates and shock preventing methods on plant height and dry matter accumulation of pearl millet varieties

Treatments	Plant height (cm)			Dry matter accumulation (g/m^2)		
	20 DAT	40 DAT	At harvest	20 DAT	40 DAT	At harvest
Varieties						
V_1	39.74	148.64	173.86	193.04	481.32	628.32
V_2	40.90	133.97	151.22	188.10	394.74	500.50
CD (p=0.05)	NS	4.10	4.47	NS	12.52	15.34
Transplanting shock preventing methods						
M_0	35.47	128.99	145.63	169.66	367.71	459.65
M_1	42.85	147.61	170.80	200.85	472.16	615.50
M_2	44.14	150.63	175.89	205.96	487.74	637.56
M_3	38.82	137.98	157.84	185.81	424.51	544.93
CD (p=0.05)	1.69	5.80	6.32	7.89	17.70	21.69
Dates of Transplanting						
D_1	37.90	134.15	150.34	176.02	390.97	498.44
D_2	42.14	146.95	170.99	200.10	468.74	607.34
D_3	40.93	142.81	166.29	195.58	454.38	587.46
CD (p=0.05)	1.47	5.03	5.47	6.83	15.33	18.79
CV (%)	8.97	8.77	8.31	8.87	8.63	8.21

NS= Non-significant

Table 2. Effect of transplanting dates and shock preventing methods on total number of tillers, leaf area and grain yield of pearl millet varieties

Treatments	Total number of tillers/plant			Leaf area (cm^2/plant)			Grain yield (kg/ha)
	20 DAT	40 DAT	At harvest	20 DAT	40 DAT	At harvest	
Varieties							
V_1	2.74	3.63	3.66	945	2015	1955	2559
V_2	2.31	2.93	2.97	841	1816	1779	1873
CD (p=0.05)	0.07	0.09	0.10	22.6	59.2	52.9	59.4
Transplanting Shock Preventing Methods							
M_0	2.26	2.85	2.90	800	1613	1604	1896
M_1	2.65	3.47	3.53	939	2071	1997	2369
M_2	2.73	3.62	3.64	972	2111	2051	2452
M_3	2.47	3.17	3.19	861	1866	1815	2147
CD (p=0.05)	0.09	0.13	0.13	32.0	83.7	74.8	84.0
Dates of Transplanting							
D_1	2.31	2.96	2.99	845	1788	1703	1966
D_2	2.68	3.50	3.54	928	2009	1976	2376
D_3	2.59	3.37	3.42	906	1950	1921	2306
CD (p=0.05)	0.08	0.12	0.12	27.7	72.5	64.8	72.7
CV (%)	8.02	8.71	8.66	7.6	9.3	8.6	8.10

NS= Non-significant

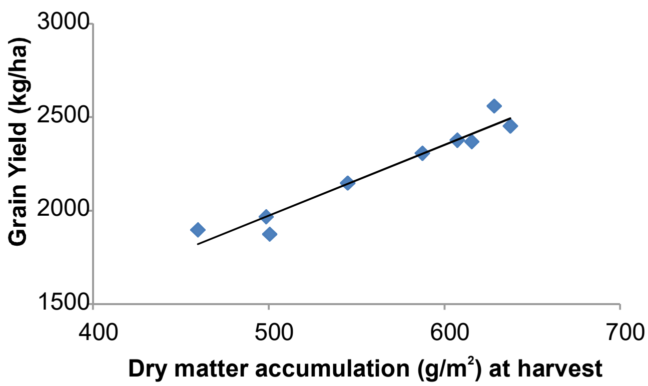

Fig. 3. Relationship between dry matter accumulation and grain yield of pearl millet

dry matter accumulation by crop (Fig. 3). It revealed that 1g/m^2 dry matter accumulation increased the grain yield by 3.78 kg/ha.

CONCLUSION

Pearl millet cultivar RHB-173 transplanted during the first 1st fortnight of July with a foliar spray of triacontanol @ 0.25 ml/litre prior to two days of transplanting in a pearl millet nursery as a shock preventing method recorded better crop growth and provided significantly higher grain yield.The research findings are useful for the farmers of semi-arid ecosystem of Rajasthan, where pearl millet growers suffers badly due to delayed and uneven distribution of monsoon rains and resulted in patchy stand of crop. Due to transplanting technology of pearl millet, farmers will be able to raise pearl millet seedlings during the off season in nursery and able to transplant pearl millet in time.

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AUTHORS CONTRIBUTION

The experiment was carried out and original manuscript draft prepared by VL Yadav. R Saxena: designed the methodology of experiment. L Verma: helped in field data collection, reviewing and editing manuscript. P Yadav: helped in statistical analysis, DL Kikraliya: preparation of figures. UN Shukla: contributed in research design, reviewing the final draft and editing.

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