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Impact of drought mitigation techniques on pigeon pea (*Cajanus cajan* L. Milli sp.) yield

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Abstract
The study titled "Impact of drought mitigation techniques on pigeon pea (*Cajanus cajan* L. Milli sp.) yield" was carried out at the Agricultural Research Station, Badnapur during the K*harif* season of 2016-17. The experimental field was properly levelled and had good drainage. The soil had a clayey texture, moderate nitrogen availability, low phosphorus availability, high potassium availability, and a moderately alkaline pH. The environmental conditions during the experiment were favourable for the normal growth and maturity of the pigeon pea crop. The experiment followed a randomized block design with ten treatments, with one treatment being replicated three times. The gross plot size of each experimental unit was 5.4 m x 4.0 m, while the net plot size was 3.6 m x 3.6 m. Sowing was done on July 02, 2016 using the dibbling method with a spacing of 90 x 20 cm. Seed treatment, pest and disease management, and fertilizer management were carried out according to the recommended practices for all treatments.
The findings indicated that the yield attributing characteristics, yield, and harvest index of pigeon pea were significantly higher with the application of Pusa hydrogel @ 2.5 kg ha^{-1} combined with mulching using organic residue @ 5 t ha^{-1} (T_9) compared to the other treatments. Following closely were the treatments involving Vermicompost @ 2.5 t ha^{-1} combined with Pusa hydrogel @ 2.5 kg ha^{-1} (T_7), and the treatment (T_8) which included FYM @ 5 t ha^{-1} combined with Pusa hydrogel @ 2.5 kg ha^{-1}, along with a 2% KH_2PO_4 spray during flowering and a 2% KNO_3 spray during pod development stage. The outcome of the current investigation concluded that the treatment (T_9) involving Pusa hydrogel @ 2.5 kg ha^{-1} combined with mulching using organic residue @ 5 t ha^{-1} was advantageous for farmers.

Keywords: Impact, mitigation, pigeon, pea, *Cajanus cajan* L.

Introduction
Pigeon pea, scientifically known as *Cajanus cajan* L. Millsp., is a significant pulse that plays a crucial role in the daily diet. Commonly referred to as red gram or tur, it is the second most important pulse crop in India, following chickpea. In the year 2016-17, India had 5.21 million hectares of land dedicated to pigeon pea cultivation, with a production of 4.23 million tonnes and a productivity rate of 826 kg ha^{-1}. Specifically in Maharashtra, there were 15.33 lakh hectares of pigeon pea cultivation, resulting in a production of 11.70 lakh tonnes and a productivity rate of 764 kg ha^{-1}. In Marathwada, the area under pigeon pea cultivation was 5.95 lakh hectares, with a production of 4.47 lakh tonnes and a productivity rate of 759 kg ha^{-1} (Anonymous, 2017) [2]. India holds a dominant position in pigeon pea production, accounting for 90% of the world's total output. This protein-rich legume crop is essential for the semi-arid and subtropical regions, especially considering the widespread shortage of pulses to meet domestic demands. Pigeon pea is the leading *Kharif*-grown legume in terms of both area and production. Despite ranking sixth globally in terms of area and production among grain legumes like beans, peas, and chickpeas, pigeon pea is utilized in a more versatile manner.
Drought poses a significant environmental challenge to plant survival and productivity, leading to food insecurity in tropical regions. Mitigation refers to proactive measures taken before or at the onset of drought to minimize its impacts. Mitigating drought entails various agricultural practices such as securing extra water sources and conserving existing water resources. In line with this, a study titled "Impact of drought mitigation techniques on pigeon pea (*Cajanus cajan* L Milli sp.) yield" was carried out.

Materials and Methods
An experiment was conducted at Agricultural Research Station Badnapur in randomized block design with ten treatments replicated for three times during *Kharif 2016*-17. The experimental site had clay soil texture and was fairly good in terms of nutrient status.

The experiment aimed to test the recommended variety BSMR-853 of pigeon pea along with ten different treatments. These treatments included seed hardening with $CaCl_2$ (2%) (T_1), Vermicompost application @ 2.5 t ha^{-1} (T_2), FYM application @ 5 t ha^{-1} along with 2% KH_2PO_4 spray at flowering and 2% KNO_3 spray at pod development stage (T_3), mulching with organic residue @ 5 t ha^{-1} (T_4), Pusa hydrogel application @ 2.5 kg ha^{-1} (T_5), seed hardening with $CaCl_2$ along with Pusa hydrogel application @ 2.5 kg ha^{-1} (T_6), Vermicompost application @ 2.5 t ha^{-1} along with Pusa hydrogel application @ 2.5 kg ha^{-1} (T_7), FYM application @ 5 t ha^{-1} along with Pusa hydrogel application @ 2.5 kg ha^{-1}, 2% KH_2PO_4 spray at flowering, and 2% KNO_3 spray at pod development stage (T_8), Pusa hydrogel application @ 2.5 kg ha^{-1} along with mulching with organic residue @ 5 t ha^{-1} (T_9), and a control treatment (T_{10}). The gross plot size was 5.4 m x 4.0 m, while the net plot size was 3.6 m x 3.6 m. The crop was sown on July 02, 2016 using the dibbling method with a spacing of 90 cm x 20 cm.

The data collected included the number of pod plants, weight of pod plants (grams), and weight of seeds per plant (grams) from five selected plants in each net plot at harvest. A sample of 100 seeds was randomly drawn from each net plot, and their weights were recorded as Test weight (grams). The plants from each net plot were harvested, threshed, and the seeds were cleaned through winnowing. The yield of seeds per plot (kilograms) was then converted to yield per hectare. The straw yield per net plot was determined by calculating the difference between the total produce weight and the seeds weight per net plot, and then converting it to a hectare basis. The biological yield was recorded by the following formula in kg.

Biological yield = Seed yield + Straw yield

Harvest index was calculated by using following formula.

$$\text{H.I. (\%)} = \frac{\text{Economical yield}}{\text{Biological yield}} \times 100$$

All the data collected were subjected to statistical analysis and the result were tested by adopting 'F' test at 0.05 probability level.

Results

Yield and yield attributes

Data on yield attributes *viz.*, number of pods plant^{-1}, number of seeds pod^{-1}, weight of plant^{-1}, weight of seed plant^{-1} and seed index are presented in Table 1.

Mean number of pods plant^{-1}

The data presented in table 1 indicated that mean number of pods plant^{-1} at harvest was 101.46.Higher mean number of pods plant^{-1} at harvest was observed with treatment Pusa hydrogel @ 2.5 kg ha^{-1} + mulching with organic residue @ 5 t ha^{-1}(T_9) was recorded significantly a greater number of pods plant^{-1} (135 pods plant^{-1}) over the rest of the treatments whereas it was at par with the treatment vermicompost @ 2-5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1}(T_7) (122 pods plant^{-1}) while the significantly lowest number of pods plant^{-1} was recorded treatment control (T_{10}).

Number of seeds pod^{-1}

The data regarding number of seeds pod^{-1} presented in Table 1 and mean number of seed pod^{-1} at harvest was (3.59). The effect of various treatment on number of seed pod^{-1} was not significant. The treatment Pusa hydrogel @ 2.5 kg ha^{-1} + mulching with organic residue @ 5 t ha^{-1} (T_9) was recorded maximum seeds pod^{-1} (4.0) compared to all other treatments while significantly lower number of seeds pod^{-1} (2.9) was observed in control treatment (T_{10}).

Weight of pods plant^{-1}(g)

Data pertaining to on weight of pods plant^{-1} is presented in Table 1 and average weight of pod plant^{-1} was 50.55 g in table. The treatment Pusa hydrogel @ 2.5 kg ha^{-1} + mulching with organic residue @ 5 t ha^{-1} (T_9) recorded significantly higher weight pod plant^{-1}(70.28 g plant^{-1}) over the rest of treatments, whereas it was at par with vermicompost @ 2-5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1} (T_7) while the lowest weight pod plant^{-1}(31.08 g plant^{-1}) was recorded by the control (T_{10}).

Weight of Seed plant^{-1} (g plant^{-1})

Data pertaining on seed weight plant^{-1} (g) as affected by various treatments are presented in Table 1 and average seed weight plant^{-1} was 26.69 g. Pusa hydrogel @ 2.5 kg ha^{-1}+ mulching with organic residue @ 5 t ha^{-1} (T_9) recorded significantly superior seed weight plant^{-1} (35.70 gm plant^{-1}) over all other the treatments. However, it was at par with the Vermicompost @ 2.5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1} (T_7) and the treatment (T_8) FYM @ 5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1} + 2% KH_2PO_4 spray at flowering + 2% KNO_3 spray at pod development stage while the significantly lowest weight of seed pod^{-1} (19.5 g plant^{-1}) by treatment control(T_{10}).

Seed index (g)

The data on seed index is produced in Table 1 and it was averaged about 11.2 g. The effect of drought mitigation treatments on seed index was found to be nonsignificant. However, the treatment Pusa hydrogel @ 2.5 kg ha^{-1}+ mulching with organic residue @ 5 t ha^{-1} (T_9) was recorded maximum seed index (11.9 g) compared to all other treatments, while the lowest seed index was observed in control treatment (10.3 g).

Seed yield (kg ha^{-1})

The data pertaining to seed yield (kg ha^{-1}) are presented in Table 2. The mean seed yield was recorded 1455 kg ha^{-1}. The perusal data presented in Table 20 showed that seed yield of pigeon pea influenced significantly by different drought mitigation practices. Effect of different drought mitigation practices on straw yield was found be significant. Pusa hydrogel @ 2.5 kg ha^{-1} + mulching with organic residue @ 5 t ha^{-1} the treatment (T_9) recorded significantly higher seed yield kg ha^{-1}(1912 kg ha^{-1}) of pigeon pea which was found at par with treatment (T_7) Vermicompost @ 2.5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1}(1769 kg ha^{-1}) and the treatment (T_8) FYM @ 5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1} + 2% KH_2PO_4 spray at flowering + 2% KNO_3 spray at pod development stage (1666 kg ha^{-1}) while the significantly lowest seed yield kg ha^{-1} (1004 kg ha^{-1})was recorded by the treatment control (T_{10}).

Straw yield (kg ha^{-1})

The data pertaining to straw yield (kg ha^{-1}) are presented in Table 2 and average straw yield was 4795 kg ha^{-1}.Effect of different drought mitigation practices on straw yield was found significant. The higher straw yield kg ha^{-1} (5725 kg ha^{-1}) was recorded in the treatment Pusa hydrogel @ 2.5 kg ha^{-1} + mulching with organic residue @ 5 t ha^{-1} (T_9) which was significantly superior over the rest of treatments, where which was found at par with the treatment (T_7) Vermicompost @ 2.5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1}(5614 kg ha^{-1}) and the treatment (T_8) FYM @ 5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1} + 2% KH_2PO_4 spray at flowering + 2% KNO_3 spray at pod development stage (5571kg ha^{-1}). The significantly lowest straw yield kg ha^{-1} (3958 kg ha^{-1}) was recorded by the treatment control (T_{10}).

Biological yield (kg ha^{-1})

The data pertaining to biological yield (kg ha^{-1}) are presented in Table 2. average biological yield was 6250.2 kg ha^{-1}.Effect of different drought management practices on biological yield was found to be significant. The higher biological yield kg ha^{-1} (7637kg ha^{-1}) was recorded in the treatment Pusa hydrogel @ 2.5 kg ha^{-1} + mulching with organic residue @ 5 t ha^{-1} (T_9) which was significantly superior over the control (T_{10}) which was recorded significantly lowest biological yield kg ha^{-1}(4962 kg ha^{-1}), where which was found at par with the treatment (T_7) Vermicompost @ 2.5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1}(7383 kg ha^{-1}) and the treatment (T_8) FYM @ 5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1} + 2% KH_2PO_4 spray at flowering + 2% KNO_3 spray at pod development stage (7238 kg ha^{-1}).

Harvest index (HI)

The data pertaining to harvest index are presented in Table 2 and average harvest index was 23.From the data it was observed that the effect of drought mitigation management practices on harvest index was found to be non-significant. The treatment Pusa hydrogel @ 2.5 kg ha^{-1} + mulching with organic residue @ 5t ha^{-1} (T_9) obtained maximum harvest index (25.03) followed by the treatment (T_7) Vermicompost @ 2.5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1}(23.96), the treatment (T_8) FYM @ 5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1}+ 2% KH_2PO_4 spray at flowering + 2% KNO_3 spray at pod development stage (23.01) and the treatment (T_6) Seed hardening with $CaCl_2$ + Pusa hydrogel @ 2.5 kg ha^{-1}(22.75). The significantly lowest harvest index (20.03) recorded by the treatment control (T_{10}).

Discussion

Yield attributes: The yield of a crop is determined by its growth and various yield attributes. The factors that contribute to yield, such as the number of pods per plant, number of seed pods plant^{-1}, weight of pods plant^{-1}, weight of seeds plant^{-1}, and seed index, were significantly influenced by different drought mitigation treatments.

Among the various practices for mitigating drought, the treatment (T_9) involving the use of Pusa hydrogel @ 2.5 kg ha^{-1} and mulching with organic residue @ 5 t ha^{-1} demonstrated the highest number of pods plant^{-1}, number of seed pods plant^{-1}, weight of pods plant^{-1}, and weight of seeds plant^{-1} compared to the other treatments. Following closely were treatments (T_7) and (T_8), which showed similar increases in the number of pods plant^{-1}, number of seed pods, weight of pods plant^{-1}, and weight of seeds plant^{-1} due to the application of Pusa hydrogel and mulching. This improvement can be attributed to the increased water holding capacity and soil moisture percentage resulting from the use of Pusa hydrogel and mulching, which in turn led to better growth attributes such as the number of branches and leaves. These growth attributes facilitate the enhanced translocation of assimilates from source to sink. On the other hand, the control treatment (T_{10}) exhibited lower numbers of pods plant^{-1}, number of seed pods plant^{-1}, weight of pods plant^{-1}, and weight of seeds plant^{-1} compared to the other treatments. Similar results were reported by Schonfeld *et al*. (1988) [9] for the use of Pusa hydrogel and by Virdia and Patel (2000) [10] for mulching.

Yield: The yield of a crop is determined by its growth and various yield attributes. The different drought mitigation treatments had a significant impact on the contributing factors of yield, such as seed yield (kg ha^{-1}), straw yield, and biological yield (kg ha^{-1}).

Among the different methods used to mitigate drought, the combination of T_9, Pusa hydrogel @ 2.5 kg ha^{-1} and mulching with organic residue @ 5 t ha^{-1} resulted in higher seed yield (kg ha^{-1}), straw yield (kg ha^{-1}), and biological yield (kg ha^{-1}) compared to other treatments. Following closely were T_7 and T_8, which showed similar results. The improved seed yield, straw yield, and biological yield due to Pusa hydrogel + mulching can be attributed to increased water holding capacity and soil moisture, leading to better growth and yield attributes such as number of branches, leaves, pods plant^{-1}, seeds pod^{-1}, weight of pods plant^{-1}, and weight of seeds plant^{-1}, facilitating enhanced assimilate translocation from source to sink. The lowest seed yield, straw yield, and biological yield were observed in the control treatment T_{10}. The increase in seed yield can be linked to effective drought control during the critical crop period, reducing biotic stress and creating a better environment (moisture, nutrients, sunlight, etc.) for improved growth and yield. Similar results were reported by Schonfeld *et al.* (1988) [9] for Pusa hydrogel. These findings align with studies by Ajula & Cheema (1983) [3], Mandal and Ghosh (1984) [7], Gajera (1994) [5], Mandal and Ghosh (1984) [7] and Anon. (1999) [1] on mulching, as well as Bhan and Khan (1980) [4] and Virdia and Patel (2000) [10] on higher cotton yield under paddy straw mulch compared to no mulch treatment.

Harvest index (HI)

Among the various practices used to mitigate drought, the treatment involving the application of Pusa hydrogel @ 2.5 kg ha^{-1} and mulching with organic residue @ 5 t ha^{-1} (T_9) demonstrated the highest harvest index compared to the other treatments. Following T_9, treatments T_7 and T_8 also showed relatively high harvest indexes. The improved harvest index observed in the Pusa hydrogel + mulching treatment can be attributed to its ability to increase water holding capacity and soil moisture percentage. This, in turn, resulted in better growth and yield attributes such as the number of branches, number of leaves, Weight of pods plant^{-1}, Weight of seeds plant^{-1}, seed yield, straw yield, and biological yield. These attributes contribute to enhanced translocation of assimilates from source to sink. On the other hand, the control treatment (T_{10}) recorded the lowest harvest index. Similar findings were reported by Sampath Kumar *et al.* (2006) [8] for mulching and Islam *et al.* (2011) [6] in maize for Pusa hydrogel.

Table 1: Number of pods plant^{-1}, Number of seeds pod^{-1}, Weight of pods Plant^{-1} (g), Weight of seeds Plant^{-1} (g) and Seed index (g) of pigeon pea as influenced by various treatments at harvest

Tr. No	Treatments	Number of pods plant^{-1}	Number of seeds pod^{-1}	Weight of pods Plant^{-1}	Weight of seed Plant^{-1}	Seed Index
T_1	Seed hardening with $CaCl_2$ (2%)	98.00	3.60	46.86	25.00	11.20
T_2	Vermicompost @ 2.5 t ha^{-1}	105.3	3.80	51.52	26.7	11.30
T_3	FYM @ 5 t ha^{-1} +2% KH_2PO_4 spray at flowering + 2% KNO_3 spray at pod development stage	95.30	3.50	45.76	24.00	10.70
T_4	Mulching with organic residue @ 5 t ha^{-1}	93.36	3.50	44.88	24.40	11.20
T_5	Pusa hydrogel @ 2.5 kg ha^{-1}	83.44	3.40	40.32	23.00	11.20
T_6	Seed hardening with $CaCl_2$ + Pusahydrogel @ 2.5 kg ha^{-1}	106.0	3.70	51.80	27.00	11.40
T_7	Vermicompost @ 2.5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1}	122.0	3.80	62.30	31.40	11.70
T_8	FYM @ 5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1}+ 2% KH_2PO_4 spray at flowering + 2% KNO_3 spray at pod development stage	115.00	3.70	60.70	30.20	11.50
T_9	Pusa hydrogel @ 2.5 kg ha^{-1} + mulching with organic residue @ 5 t ha^{-1}	135.00	4.00	70.28	35.70	11.90
T_{10}	Control	61.21	2.9	31.08	19.50	10.30
SE + m		5.32	0.19	2.98	1.34	0.51
C.D. at 5%		15.81	NS	8.85	3.97	NS
General Mean		101.46	3.59	50.55	26.69	11.24

Table 2: Seed yield (kg ha^{-1}), straw yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%) of pigeon pea as influenced by various treatments at harvest

Treatment No	Treatments	Seed Yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
T_1	Seed hardening with $CaCl_2$ (2%)	1333	4526	5859	22.75
T_2	Vermicompost @ 2.5 t ha^{-1}	1458	4520	5979	24
T_3	FYM @ 5 t ha^{-1} +2% KH_2PO_4 spray at flowering + 2% KNO_3 spray at pod development stage	1326	4401	5727	23.14
T_4	Mulching with organic residue @ 5 t ha^{-1}	1317	4410	5727	22.99
T_5	Pusa hydrogel @ 2.5 kg ha^{-1}	1293	4234	5527	23.39
T_6	Seed hardening with $CaCl_2$ + Pusahydrogel @ 2.5 kg ha^{-1}	1470	4992	6462	22.75
T_7	Vermicompost @ 2.5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1}	1769	5614	7383	23.96
T_8	FYM @ 5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1}+ 2% KH_2PO_4 spray at flowering + 2% KNO_3 spray at pod development stage	1666	5571	7237	23.01
T_9	Pusa hydrogel @ 2.5 kg ha^{-1}+ mulching with organic residue @ 5 tha^{-1}	1912	5725	7637	25.03
T_{10}	Control	1004	3958	4962	20.03
SE + m		84.28	306.6	368.5	0.87
C.D. at 5%		250.41	911.17	1095.03	NS
General Mean		1454.9	4795.2	6250.2	23

Conclusion

Considering the losses caused by drought in pigeon pea based on one season data on different drought mitigation practices the following broad conclusion could be drawn. The yield parameters of pigeon pea were superior with the Pusa hydrogel @ 2.5 kg ha^{-1} + mulching with organic residue @ 5 t ha^{-1} (T_9) over the rest of treatments, followed by the Vermicompost @ 2.5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1} (T_7) and the treatment (T_8) FYM @ 5 t ha^{-1} + Pusa hydrogel @ 2.5 kg ha^{-1}+ 2% KH_2PO_4 spray at flowering + 2% KNO_3 spray at pod development stage. The result of present investigation concluded that the treatment (T_9) Pusa hydrogel @ 2.5 kg ha^{-1} + mulching with organic residue @ 5 t ha^{-1}gives higher grain yield.

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