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Harnessing Polyembryony to Counter Rainfall Variability in Churu District, Rajasthan: Pathways to Enhanced Agricultural Productivity

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Abstract

Churu district in Rajasthan faces increasing rainfall variability: erratic onset, intra-seasonal dry spells, and occasional extremes. These changes compromise seedling establishment, crop uniformity, and yield stability, especially in rain fed crops. Polyembryony, the phenomenon where a single seed produces multiple embryos (often including nucellar clones of the mother plant), presents a potential tool for enhancing agricultural resilience.

This review paper examines

(a) Rainfall pattern changes and their effects in Churu,

(b) Biological basis of polyembryony and examples in India and elsewhere,

(c) How polyembryony might ameliorate yield losses under variable rainfall,

(d) Evidence from similar interventions and case studies, and

(e) Recommendations for deployment in Churu to strengthen Rajasthan's agricultural output.

Findings suggest that combining polyembryonic seed sources with improved agronomic practices may increase yield by 15-30% in rain fed pearl millet and pulse crops, reduce risk in dry years, and contribute to overall agricultural strength at district/state/national levels. Key challenges include identifying suitable polyembryonic varieties, ensuring genetic stability, seed systems infrastructure, and farmer adoption. Policy and research interventions are proposed.

1. Introduction

1.1 Background: Churu District and Changing Rainfall

Churu district, situated in the arid to semi-arid zone of Rajasthan, has agricultural lands largely dependent on monsoon rains. Climatic data for the period 1991-2020 show Churu has a mean annual rainfall around 406.4 mm, with a standard deviation of ~139.5 mm, indicating high inter-annual variability. In that period, the driest year recorded ~162.2 mm and the wettest ~660.3 mm. Such variability, along with delayed onset of monsoon and frequent intra-monsoon dry spells, undermines crop establishment and yield. Recently, climate observations also report record rainfall in June 2025: Churu recorded 85.1 mm in 24 hours, breaking previous June records (~81.9 mm in 1988), and indicating increasing extremes. These patterns signify both growing unpredictability and larger fluctuations in amount/time.

1.2 Problem Statement

Rain fed crops like pearl millet (bajra), pulses (moong, moth), and local varieties suffer from seedling loss, uneven crop stand, delayed sowing or re-sowing, and overall lower yields. Traditional breeding and improved agronomic practices help, but variable rainfall still imposes yield ceilings and increases risk.

1.3 Polyembryony as a Potential Solution

Polyembryony is a trait in which a single seed produces more than one embryo. Often, some embryos are nucellar (clonal, genetically identical to the mother plant), ensuring propagation of desirable maternal traits; others are zygotic. This trait can help in several ways: multiple seedlings per seed increase chances of at least one surviving; uniformity can be maintained via the clonal embryos; risk due to seedling mortality is reduced; breeders can fix maternal traits without repeated hybridization.

1.4 Purpose, Scope, and Central Argument

This paper reviews existing literature and data to argue that selecting or introducing polyembryonic varieties/seed sources in Churu can significantly increase yield, reduce risk from rainfall variability, and contribute to making Rajasthan a stronger agricultural state and India more self-reliant in food security and agro-industry. It aims to (i) present what is known about rainfall change in Churu; (ii) synthesize research on polyembryony; (iii) link polyembryony potential to crop yield and risk mitigation; (iv) draw lessons from similar cases; (v) propose a roadmap for Churu.

2. Literature Review

2.1 Rainfall Variability, Trends, and Agricultural Impacts in Churu / Arid Rajasthan

The study of rainfall in Churu (1991-2020): mean ~406.4 mm, high coefficient of variation (~30-33%), and yearly extremes from ~ 162 mm (driest) to ~ 660 mm (wettest).

Rainfall shifts in Rajasthan: some districts, including Churu, have seen more intense rainfall in early monsoon months but deficits in critical mid-monsoon periods. Reports from IMD and news sources show increasing frequency of extremes (very heavy single-day rainfall) and longer dry spells.

Agronomic impact: front line demonstration (FLD) studies in Churu for pearl millet show yield increases of ~24.8% when improved practices are adopted vs. local farmer’s practice under rain fed conditions.

Another FLD in dry land areas (2018-22) in Rajasthan: improved hybrids (MPMH-17, HHB-299) plus recommended practices yielded 16.42-23.40% higher grain yield over farmer’s practice.

These studies show that while agronomic improvements can boost yield under rain fed conditions, the dependency on rainfall pattern remains high. Seedling establishment under early or erratic rainfall remains a bottleneck.

2.2 Polyembryony: Definitions, Mechanisms, and Examples

Definition & Types: Polyembryony is the occurrence of more than one embryo within a seed. Two main types: nucellar polyembryony (clonal, maternal origin) and zygotic polyembryony (sexual origin). The nucellar embryos allow clonal propagation of maternal genotype.

Examples in India:

1. Mango rootstocks: A study of three salt-tolerant mango rootstocks (Olour, Kurukkan, 13-1) found varying extents of polyembryony: Kurukkan showed ~74.43% polyembryony, 13-1 ~51.85%, Olour ~33.15%. Average number of seedlings per stone was highest in Kurukkan (~2.35).

2. Langsat (Lansium domesticum) in Nilgiris (Tamil Nadu): assessment of fruiting and seed polyembryony with morphological and ecological correlations.

Advantages cited in literature:

Seedling insurance: multiple embryos increase chances under adverse environmental conditions.

Uniformity: nucellar embryos are genetically identical to mother, preserving desirable traits.

Rapid propagation of superior genotypes (esp. in rootstocks, fruit trees).

Limitations noted: in some cases, zygotic embryos also occur, complicating purity; sometimes lower vigor in some clones; need to identify percentage of nucellar vs. zygotic; sometimes not present in major cereals/pulses.

2.3 Yield Enhancement and Agronomic Interventions under rain fed Conditions

FLD studies in Churu for pearl millet (2018-2022) demonstrate that using improved technologies (hybrid seeds, fertilization, weed, and moisture management) gives ~24.75% higher grain yield relative to farmer's practices. Grain yield under demonstration: 1349 kg/ha vs. local ~1081 kg/ha. Additional return ~Rs 6597/ha, investment ~Rs 1240/ha.

Hybrid MPMH-17 performance under rain fed conditions: gave ~20.6 quintals/ha (≈2060 kg/ha) in adopted villages; ~18.4% higher over local for seed yield; straw yield ~20% higher.

These show that yield improvements are possible via current agronomic improvements even without polyembryony traits, but that seedling survival and plant stand are still major risks.

3. How Polyembryony could Address Rainfall-Related Challenges & Increase Yield in Churu

Here I lay out mechanisms by which polyembryony could help, and modelled/estimated gains, drawing from literature plus local data.

3.1 Mechanisms / Pathways

Polyembryony Advantage

Poor seedling establishment due to delayed or patchy rains - Multiple embryos per seed increase probability that at least one embryo germinates and survives in variable moisture conditions.

Re-sowing or reseeding costs (seed cost, labour) when initial sowing fails with multiple embryos, less dependence on reseeding; more efficient use of seed.

Uniformity of stand and trait retention - Nucellar embryos (maternal clones) allow uniformity; desired drought/heat tolerant traits fixed.

Risk in dry years / drought / extreme variation - Clonal embryos derived from maternal plants already adapted could maintain resilience; loss of zygotic seedlings less damaging.

Breeding / seed multiplication efficiency - once polyembryonic clones of desired traits identified, multiplication is easier and cheaper; reduces time for introducing resilient germplasm.

3.2 Estimated Yield Gains & Risk Mitigation

Based on FLD data, improved agronomic practices give ~20-25% yield boost under rain fed conditions. If polyembryony adds further buffer for seedling survival (say reduces seedling mortality by 10-20%), then combined gains could push yield upward of 30-35% over baseline in "good but risky" years, and reduce yield losses in bad years significantly.

For example, assume farmer's pearl millet yield in Churu ~1,000 kg/ha. With improved agronomy (as per FLDs), yields rise to ~1,250 kg/ha. If polyembryony helps ensure better establishment, perhaps only 5-10% reseeding needed, consistent plant stand, then yield might further rise to ~1,350-1,400 kg/ha in moderate years, while in drought years, the fall back yield may improve by ~10-15%.

3.3 Possible Crops & Varieties in Churu Amenable to Polyembryony

Fruit trees / tree crops: Mango rootstocks already show polyembryony (Olour, Kurukkan). For orchards or agro-forestry in marginal lands.

Pulses / minor crops: Need to survey local germplasm for polyembryony occurrence. Literature is sparse, but possible in wild/semi-wild relatives.

Pearl millet: As major staple; if breeding or genetic introgression can bring in polyembryony traits (if they exist or can be induced), that would be high value.

4. Case Studies / Examples

4.1 Mango Rootstocks (Salt Tolerant)

The study "Studies on extent of polyembryony in salt tolerant mango rootstocks" (Olour, Kurukkan, 13-1) found high levels of polyembryony (Kurukkan ~74.43%) with average seedlings per seed up to ~2.35. This shows that for tree species, polyembryony is usable and may help ensure better establishment under stress (salinity, water stress). Though mango is not a staple crop in Churu, in plantations and agro-forestry settings this may reduce losses due to failed germination / seedling mortality.

4.2 FLDs in Pearl Millet Hybrids

As noted, MPMH-17 hybrid plus improved agronomic package in Churu and other dry land areas led to yield improvements of ~18-23%. These successes show potential ceiling of yield gains when combining improved genetics and management. Adding polyembryony may raise the baseline (seed quality, seedling survival) thus pushing those ceilings further and making yields more stable year to year.

5. Challenges, Constraints, and Gaps

Lack of existing polyembryonic trait data in cereals/pulses: Most literature is in fruit trees, rootstocks; little known about millet, moong, moth. Need surveys or screening of local germplasm.

Distinguishing zygotic vs. nucellar embryos: Genetic/molecular tools needed (e.g., SSR markers), which require laboratory infrastructure, funding.

Seed system and multiplication: Even if polyembryonic clones are identified, scaling up seed production, maintaining purity, distribution to farmers is complex.

Potential trade-offs: Clonal embryos are genetically identical; risk reduced variety might increase vulnerability to pests/diseases. Also, vigor of nucellar vs. zygotic embryos may differ: sometimes zygotic seedling grows more vigorously.

Acceptance by farmers: Need awareness, demonstration of benefits; some farmers may prefer traditional seeds, hybrids etc.

Policy, regulatory and funding constraints: Agricultural research priorities; availability of grants for germplasm screening, plant breeding; extension services capacity.

6. Recommendations / Roadmap for Churu

To realize the benefits of polyembryony under the changed rainfall pattern in Churu, the following steps are recommended:

1. Germplasm Survey & Screening

Collect local landraces of fruit trees, pulses, minor crops, tree crops to examine for natural polyembryony. Employ botanical, morphological screening (number of seedlings per seed) and molecular marker techniques (SSR, microsatellites) to distinguish embryo origin.

2. Breeding Programs

Cross or select among lines showing polyembryony + drought/heat/early-maturation traits. Test these lines under Churu's typical rainfall variability (simulated stress trials, dry year / good year comparisons).

3. Integration with Improved Agronomic Practices

Use improved hybrids (like MPMH-17), recommended fertilizer, improved sowing date, weed management etc., as done in FLDs. Polyembryony would add seedling survival buffer. Moisture conservation techniques (mulching, soil conditioning, water harvesting) to reduce deficit stress.

4. Front Line Demonstrations & Pilot Projects

Set up pilot plots in villages across Churu using polyembryonic seed sources vs. traditional, with monitoring of yield, seedling survival, cost, risk. Engage local farmers and extension agents so results are visible and trusted.

5. Seed System Strengthening

Ensure seed multiplication, quality control, and availability of polyembryonic seed sources .Protect maternal lines; ensure identity / purity of clones; address regulatory aspects.

6. Policy & Institutional Support

State agricultural universities, ICAR centres, KVKs to prioritize polyembryony research under arid agriculture. Financial incentives or subsidies for farmers using such seed sources / planting material. Incorporation into agricultural extension, training programs.

7. Monitoring & Evaluation

Collect climate, rainfall, yield, plant stand, seedling mortality, and economic return data annually. Use these to refine which species/varieties perform best; undertake cost-benefit analyses.

7. Discussion & Implications for Rajasthan and National Agriculture

If Churu can implement polyembryony-based seed sources in key crops, the yield improvement, risk reduction can help make Rajasthan's agriculture more stable. A district like Churu, if it reduces yield losses in bad years, raises baseline yields in average years, contributes to food security, reduces migration, increases farmer income.

On a state scale, widespread adoption could shift Rajasthan's agricultural productivity metrics upward, improve self-sufficiency in pulses, millets, and strengthen agro-industry (seed production, nursery business, value addition).

Nationally, with climate change increasing rainfall variability in arid/semi-arid zones, polyembryony may be a strategy applicable to other regions (e.g., parts of Gujarat, Haryana, central India). Lessons from Churu can generalize.

8. Conclusion

Rainfall patterns in Churu district have become increasingly unpredictable in amount, timing, and intensity. These changes pose serious risks to agriculture, especially in rain fed crops. Existing agronomic interventions can help but do not fully address the vulnerability of seedling establishment and risk due to rainfall variability. Polyembryony — especially when combined with advanced breeding, improved seed sources, and good agronomic practices — holds promise to increase yield (by ~20-30%), reduce risk in drought years, and contribute meaningfully to making Rajasthan an agricultural powerhouse and supporting national food security. To move forward, research to identify polyembryonic germplasm for local staple and minor crops, pilot implementations, seed system strengthening, and policy support are essential.

References

[1] Ali, S., Shivran, R. K., Chandra, S., & Gupta, A. (2023). Yield Enhancement and Gap Minimization of Rain fed Pearl Millet by Front Line Demonstration in Churu District of Rajasthan: Yield Enhancement and Gap Minimization by FLD's in Pearl Millet. Annals of Arid Zone, 62(2).

[2] Kamlesh Kumar, Srivastav, M., S. K. Singh, Ankit Singh, & Nimisha Sharma. (2018). Studies on extent of polyembryony in salt tolerant mango rootstocks. Indian Journal of Horticulture, 75(1).

[3] Singh, I., Kumar, M., Singh, G., Kumari, P., Kumari, S., Karel, A., Singh, S. K., & Rohilla, P. P. (2019). Performance of newly released pearl millet hybrid MPMH-17 for rain-fed area in Rajasthan. Indian Farming, 69(5).

[4] Anonymous. (2021). Increasing the productivity and profitability of pearl millet through Frontline Demonstration in dry land areas of Rajasthan. Annals of Arid Zone.

[5] Meteorological Department Reports / News Items on Churu Rainfall Variability (June 2025 data).

[6] Hydrometeorology of the Rajasthan Desert: Statistical Rainfall Analysis for Churu (1991-2020) Pieringer A. P. and Edwards G. J. 1965 Identification of nucellar and zygotic Citrus seedlings by infrared spectroscopy. Proc. Am. Soc. Hortic. Sci. 86: 226-234

[7] Queller D. C. 1983 Kin selection and conflict in seed maturation. J. Theor. Biol. 100: 153-172 Queller D. C. 1989 Inclusive fitness in a nutshell. In Oxford Surveys in Evolutionary Biology (eds) P. H. Harvey and L. Patridge (Oxford: University Press) 6: 73-109

[8] Rangan T. S., Murashige T. and Bitters W. P. 1969 In vitro studies of zygotic and nucellar. embryogenesis in Citrus, Proc. First Intl. Citrus Symp. 1: 225-229

[9] Rangaswamy N. S. 1959 Morphogenetic response of Citrus ovules to growth adjuvants in culture. Nature (London) 183: 735-736 Roy S. K. 1953 Embryology of Eugenia jambos L. Curr. Sci. 22: 249-25

[10] Roy S. K. 1961 Embryology of Eugenia fruticosa L. Proc. Natl. Acad. Sci., India, Sect. B. 31 : 80-87 Sachar R. C. 1955 The embryology of Argemone mexicana L-A reinvestigation. Phytomorphology 5. 200-218

[11] Sachar R. C. and Chopra R. N. 1957 A study of the endosperm and embryo in Mangifera L. Indian J. Agric. Sci. 27: 219-228

[12] Stebbins G. L. 1941 Apomixis in angiosperms. Bot. Rev. 8: 507-542

[13] Strasburger E. 1878 Ueber polyembryonie. Jen. Zeits. Naturw, 12: 647-670

[14] Swamy B. G. L. 1948 Agamospermy in Spiranthes cernua. Lloydia (Cinci) 11. 149-162

[15] Adarsh kumar and gupta b. B. 1987 twin seedlings in albizia lebbek benth. Indian j. Forestry 313

[16] Adarsh kumar, gupta b. B and uma singh 1991 polyembryony in acacia nilotica. Indian for. T 17: 124-125

[17] Adarsh kumar. Gupta b. N. And Venkatesh c. S. 1977a a note on twin in Pterospermum acerbfolium willd. Indian for. 103: 679

[18] Adarsh kumar, dhatnagar h. P. And Venkatesh c s. 1977b twin seedlings in shisham (dalbergia sisso roxb.l Indian for. 103: 770

[19] Kaur A., Ha C. O, Jong K., Sands V. E., Chan H. T., Soepadne E. and Ashton P. S. 1978 Apomixis may be widespread among trees of the climax rain forest. Nature (London) 271 : 440-442 Khoklov S. S. 1976 Evolutionary genetic problems of apomixis in angiosperms. In Apomixis and plant

[20] Breeding (ed.) S. S. Khoklov (New Delhi: Amerind) Lakshmanan K. K. and

[21] Ambegaokar K. B. 1984 Polyembryony. In Embryology of angiosperms (ed.) B. M Johri (New York: Springer-Verlag) pp. 445-474

[22] Lloyd D. G. 1989 The reproductive ecology of plants and eusocial animals. In

[23] Towards a more exact ecology (eds) J. Whitaker and P. J. Grubbs (Oxford: Blackwell) pp. 185-207

[24] Lovett Doust J. and Lovett Doust L. 1988 Socio-biology of plants: An emerging synthesis. In Plant reproductive strategies: Patterns and strategies (eds) J. Lovett Doust and L. Lovett Doust (Oxford: Oxford University Press) pp. 18-19
[25] Maheswari P. 1950 An introduction to the embryology of angiosperms (New York: Me-Graw Hill) McGinley M. A., Temme D. H. and Geber M. A. 1987 Parental investment in offspring in variable environments theoretical and empirical considerations. Am. Nat. 130: 370-39