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RESEARCH PAPER

Probability of identifying high yielding hybrids from preliminary yield trials in maize (*Zea mays* L.)

Rajashekhar M. Kachapur[1] • S. C. Talekar[2] • S. R. Salakinkop[2] • G. U. Prema[2]

Abstract: Preliminary yield trials (PYT) are important and basic trials wherein a large number of test hybrids/ genotypes are evaluated by the breeder to identify superior genotypes and advance them to the next round of evaluation. In all crop improvement programmes, every season PYT's are conducted with different objectives. However, for planning a research programme and submission of a proposal, one has to mention the deliverables i.e., at the end of PYT how many genotypes will be identified. To understand this, we compiled the data of PYT of new experimental hybrids at AICRP on maize, Dharwad centre during 2023 and 2024. Based on the criteria of 5% yield superiority over the best check initially 70 hybrids were selected from among the 602 test hybrids across two years accounting to 11.6%. Further enhancing the stringency of selection to 10% superiority, the probability of identifying significantly superior hybrids was only 7% across two years. This information holds the key for deciding and planning on development of new experimental hybrids and the probability of success.

Keywords: Maize • Hybrids • PYT • Grain yield • Probability

✉ Rajashekhar M. Kachapur: kachapurr@uasd.in

[1]Seed Unit, MARS, UAS, Dharwad-580005, Karnataka, India

[2]AICRP-Maize, MARS, UAS, Dharwad-580005, Karnataka, India

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Introduction

Maize (*Zea mays* L.) is a major coarse cereal grain crop occupying approximately 203 m. ha area around the world with a production of 1.163 MT (https:// www.upag.gov.in). Among all the cereal crops maize occupies 27% of the global area. Within the total global maize area, USA has the highest share of area (36.1%) followed by Asia (34.1%). However, USA has 49.1% of global maize production, while Asia has 32.0%. It is estimated that 15% of the global maize area is coming from the countries where maize productivity is lower than the global maize productivity of 5.5 t/ha. India is one among those countries, with productivity of 3.42 t/ ha (Agriculture statistics at a glance 2024-25: https:// desagri.gov.in).

Low productivity in India is mainly due to varied agro-climatic situations under which maize is grown from Jammu-Kashmir in the North to Tamil Nadu in the South and from Assam in the East to Gujarat in the West. In India, maize is mainly being cultivated during *Kharif* (June planting), during this period maize is exposed to different biotic and abiotic stresses, improper management practices, lack of climate resilient maize hybrids for commercial cultivation coupled with fragmented land holdings have resulted in lower productivity. To address these challenges ICAR-Indian Institute of Maize Research in co-ordination with State agricultural Universities is shouldering the responsibility. It is through the concentrated efforts of All India co-ordinated maize improvement programme supported equally by private seed industry, maize is growing at a rate of 6% CAGR in India during the last five years faster than rice and wheat (Kumar *et al.*, 2024).

However, there is noticeable yield gaps observed between the maize hybrid average yield *vs* demonstration yield (FLD) and farmer's yield. It has been reported that on an average of 4.5 q/ha yield gap in Telangana (Reddy *et al.*, 2025) and similar yield gaps have also been observed in Rajasthan (Solanki *et al.*, 2014), Karnataka (Nagaral and Patil, 2020) and Jammu and Kashmir (Prakash *et al.*, 2019). Narrowing down this yield gap in farmer's field is one of the important objectives of improving the productivity. This can be achieved through use of new genetics (hybrids), precision agronomic management and extensive field level extension. New genetics means bringing new germplasm into the breeding programme, blending of tropical with temperate material and extensive testing of new hybrid combinations. Hence, crop improvement is a continuous work and as opined by Gao *et al.* (2023). Breeders have to work continuously to identify new genetic material and develop new hybrid combinations, as these new hybrids are expected to outperform as compared to the existing leading hybrids in the market. However, improvement in yield and productivity is not in always a geometrical proportion but in linear manner and is additive in nature.

This improvement in yield is again dependent on the extent of genetic gain that is being realized through each breeding cycle. The breeding cycle consists of evaluation, selection, and recombination of the genetic resources to achieve genetic gain over time. A breeding program is the sum of breeding pipelines to achieve the breeding targets for a set of market/target segments. This breeding scheme involves CES i.e., crossing, evaluation and selection which ultimately defines a breeding strategy (Pazaran *et al.*, 2022).

Materials and methods

In line with this, efforts were continuously made at AICRP on maize, Dharwad to develop new hybrid combinations with different genetic background. To evaluate these test hybrids, as a part of CES, the preliminary yield trial (PYT) which is said to be a ubiquitous feature of breeding program (Endelman *et al.*, 2014) was employed to evaluate the newly generated test hybrids in preliminary yield trials (station trials) during *Kharif*, 2023 and 2024. Here, the main objective was to know the probability of identifying superior and high yielding hybrids at different thresholds (selection intensity) at PYT stage so that it gives a fair idea on the probability of identifying superior hybrids. The use of threshold in PYT has been suggested by Johnson (1989); Knapp (1998) and Longin *et al.* (2006).

The replicated PYT's were laid out in RCBD as well as in Alpha lattice design based on the experimental requirement and each experimental hybrid was raised in two rows of 4.0 m length following a spacing of 60 × 20 cm spacing in all the trials. All the recommended package of practice was followed to raise a healthy crop and optimum population was maintained. During *Kharif*, 2023 and 2024 there were overall 14 PYT with seven in each year. Each of these trials was laid out separately with a set of checks for each trial. In the present study, the data compiled from the PYT trials of *Kharif*, 2023 and 2024 is considered for drawing the inference. During *Kharif*, 2023 a total of 240 test hybrids were evaluated and 362 during *Kharif*, 2024. NK-6240 (National check) and DKC-9133 a popular private hybrid in Karnataka were used as checks in the trial during both the years.

Results and discussion

The summary of the PYT trials with descriptive statistics is presented in Table 1, which indicated that the grain

Table 1. Descriptive statistics with different parameters of PYT

Groups	*Kharif* 2023	*Kharif* 2024	Selected hybrids
Num of observations	240	362	140
Minimum	14.7	11.4	77.5
Maximum	142.7	100.5	142.7
Range	128	89.1	65.2
Mean ($\bar{x}$)	71.43	62.87	89.92
Standard Deviation (σ)	21.42	14.2426	11.8449
Variance (σ^2)	459.0344	202.8522	140.303
Standard Error	1.385	0.749	1.00
Sum of squares	110,168.2542	73,432.4852	19496.9574
Q1	57.1	54.29	81.9
Median	71.85	63.6	86.8
Q3	85.27	71.9	93.25
Interquartile range	28.17	17.61	11.35
Skewness	0.207	-0.2909	1.93
Excess kurtosis	0.435	0.3293	4.4259
SW p-value (W)	0.342	0.1516	0.0
KS p-value (D)	0.3026	0.5314	0.0

yield varied from 14.7 to 142.7 q/ha with a mean of 71.43 q/ha and range of 128 q/ha during *Kharif*, 2023.Whereas, during 2024 it varied from 11.4 to 100.4 q/ha with a mean of 62.87 q/ha and range of 89.1 q/ha. The Variance (σ^2) was high during *Kharif*, 23 as compared to *Kharif*, 24 (Figure 1). The standard error (SE) and SW p-value were lower during *Kharif*, 24 as compared to *Kharif*, 23 indicating that the data variability was less during *Kharif*, 2024 as compared to *Kharif*, 2023.

Further, to identify a bench mark yield so that over and above which the hybrids can be selected from PYT, the data from AICRP breeding trials at Dharwad centre from medium and late maturity of *Kharif*, 2024 was analyzed and the mean grain yield across all the trials was compiled which recorded to be 77.5 q/ha. The whole idea of developing these criteria was to know the average productivity of maize at Dharwad center across maturity groups, dates of sowing and type of hybrids. To identify the promising hybrids initially this bench mark yield was used and out of the 602 test hybrids (from *Kharif*, 2023 and 2024 together) 140 test hybrids could surpass the bench mark yield, accounting to 23.25% of the total hybrids. From among the selected hybrids, the grain yield varied from 77.5 to 142.7 q/ha (Table 1) with a mean yield of 89.92 q/ha with a range to 65.2 q/ha. Lower SD and Variance (σ^2) values indicated lesser data variability among the selected hybrids.

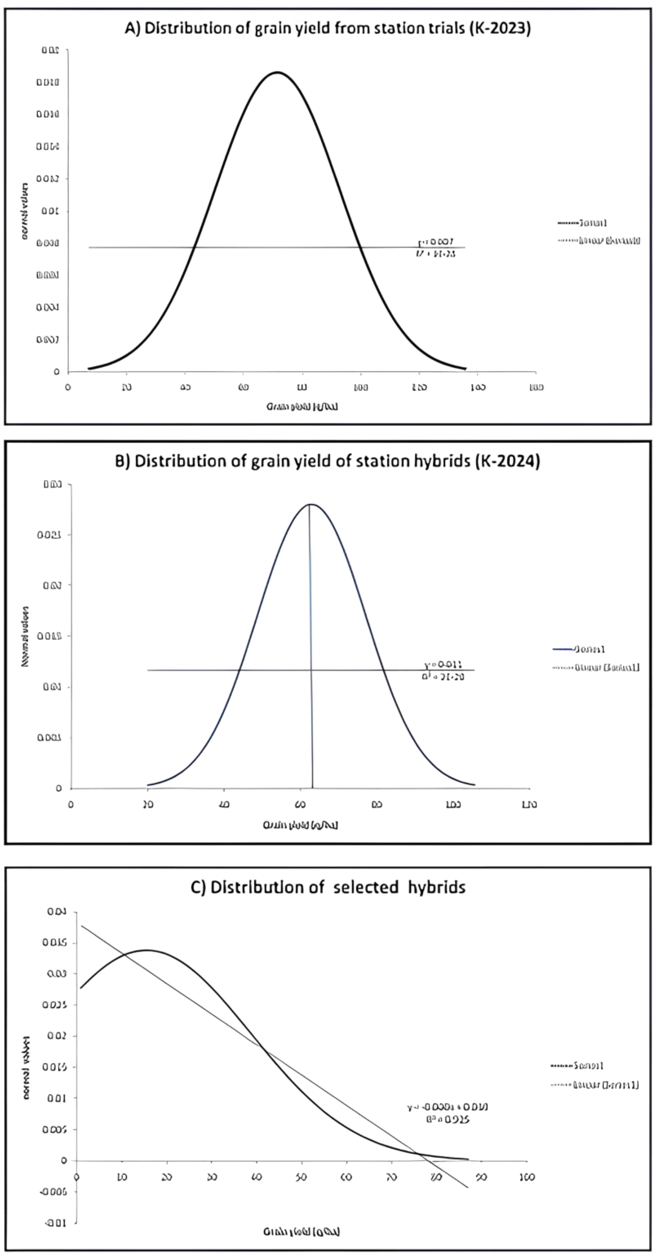

Figure 1. Distribution of grain yield A) *Kharif*-2023 B) *Kharif*-2024 C) Selected hybrids

To further up the bench mark yield or increase the stringency of selection, the mean grain yield of National check (NK 6240) and popular private hybrid (DKC 9133) was compiled from across the station trials. Among the two checks, the yield data of NK 6240 was found to be varying more than the popular private hybrid check DKC 9133 as evident from the Box plot (Figure 2). DKC 9133 was consistently performing across the trials and recorded a mean grain yield of 82.45 q/ha.

Genetic gain is said to be achieved by using only the best individuals with performances above a specific threshold for breeding (Seck *et al.*, 2023). Hence, the test hybrids were scanned using this updated bench mark yield of 82.45 q/ha. During, *kharif*, 2023 out of 240 test hybrids 69 experimental test hybrids were with grain yield higher than bench mark yield (Table 2) accounting to 28.8%. Similarly, during 2024 there were 32 hybrids with higher grain yield than the check (8.8%).

Across the years, from among the 602 hybrids, 101 test hybrids were with grain yield higher than new bench mark yield accounting to 16.8%. For promotion of any genotype the yield superiority of 5% over the best check is considered (www.iimr.res.in /ICAR-CVRC promotion guidelines), accordingly 55 hybrids during 2023 and 15 hybrids during 2024 were found superior to the new bench mark yield level accounting to 22.9 and 4.1% respectively. Across two years, 70 hybrids displayed more than > 5% yield superiority over the best check DKC 9133. This indicates that by evaluating 600 experimental test hybrids in PYT, the chance of identifying superior hybrids with more than 5 per cent yield superiority is

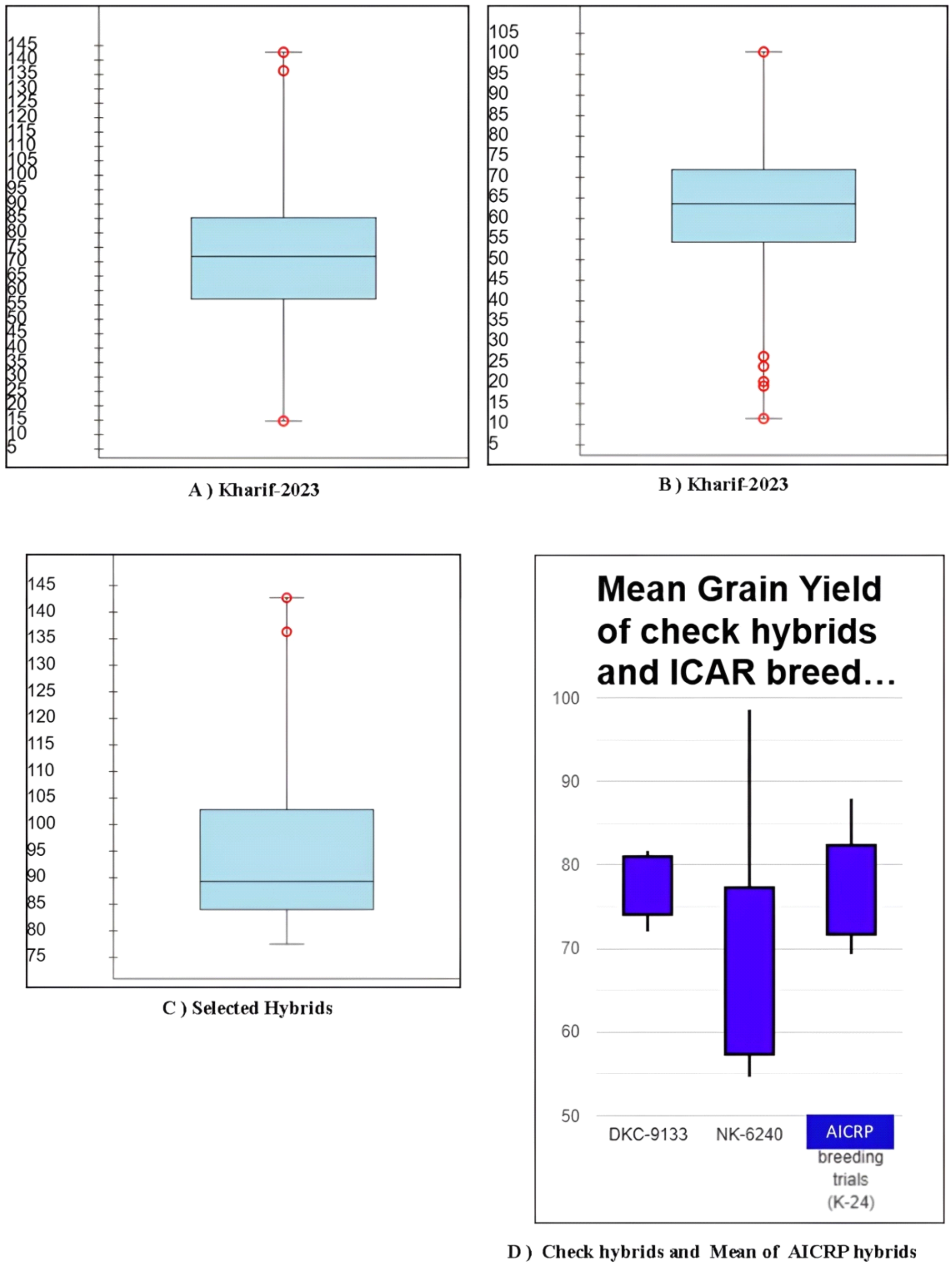

Figure 2. Box plots indicating the mean grain yield of PYT, 2023 and 2024, Selected hybrids, Check hybrids and Mean yield of AICRP Breeding trial yield

Table 2. Probability of identifying superior maize hybrids from PYT

Details	2023	% Superiority	2024	% Superiority	Total Number of hybrids	Average % Superiority
Total Number of experimental hybrids	240		362		602	
Number of hybrids surpassing the average yield criteria at Dharwad center 77.5 q/ha	85	35.41	55	15.19	140	23.25
Number of hybrids surpassing the check grain yield (DKC 9133: 82.45 q/ha)	69	28.8	32	8.8	101	16.8
Hybrids with > 5% yield superiority over DKC 9133	55	22.9	15	4.1	70	11.6
Hybrids with > 10% yield superiority over DKC 9133	37	15.4	5	1.4	42	7.0

11.6%. Ligeyo *et al.*, 2024 reported that 12% of the maize hybrids were advanced from PYT-1st year to PYT-2nd year at Kenya's highland maize breeding programme from 1999 to 2020 supporting the findings of the present study and further they have reported that only 2% of the hybrids were promoted from 2nd year to 3rd year PYT trials. Similarly, in soybean Zhou *et al.* (2022) selected 238 superior genotypes in PYT accounting to 13.4% from the population of 1773 genotypes.

Further, the hybrids selected based on evaluation at single environment (Dharwad) with a threshold of 5% yield superiority may or may not perform well in the Multi-location yield trials with different environmental background; this was our experience and also based on the data. But, increasing the number of testing environments at PYT stage, there are limitations w.r.t size of the trial, budget, manpower and also quantity of seed. To overcome these limitations, another option is to increase the stringency of selection with enhanced bench mark yield i.e., 10% yield superiority over the best check. These criteria can be useful to certain extent for promoting the test hybrids to next round of evaluation i.e. State MLT / AICRP breeding trials. Applying this threshold of > 10% yield superiority criteria over best check, out of the 240 test hybrids in 2023, 37 seven hybrids recorded more than 10% higher yield as compared to DKC 9133 accounting to 15.4%, but only 5 hybrids during 2024 accounting to only 1.4%. However, across two years 42 test hybrids recorded more than 10% grain yield superiority over the best check DKC 9133 accounting to 7.0%. Badu-Aparku *et al.*, 2023 in early maturing maize hybrids under multiple stress environments have reported a genetic gain for grain yield varying from 1.56 to 4.05% across years.

Conclusion

To conclude form the above it can be said that the probability of identifying significantly superior and high yielding hybrids from preliminary yield trials is around 7.0%. That means to say if in a conventional maize breeding programme if there are 100 new crosses for evaluation in the PYT the probability of identifying superior hybrid combinations is only seven. However, this also depends on the strength of breeding programme, genetic material under use and conduct of trial (environment, agronomic management and resource available) for PYT. This information generated from the present study can be used a guideline for planning and execution of a breeding program.

Author's contribution

Conceptualization of work, implementation of experiment and manuscript draft (RMK), assisted in execution of experiment and draft (SCT), review collection, agronomic management and proof reading of manuscript (SRS and GUP).

Declaration

The authors declare no conflict of interest

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