

Cultivar Options for Increasing Pearl Millet Productivity in Arid Regions

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ABSTRACT

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is traditionally a dry land crop, cultivated mostly in marginal environments of the arid and semi-arid regions, characterized by low rainfall, sandy soils with low fertility. This crop is primarily cultivated for grain purpose, but is also valued for its stover and fodder. The dual purpose nature of pearl millet offers both food and fodder security in the arid and semi-arid tropical regions of the country. Out of 9.43 m ha of pearl millet area in India, about 4.38 m ha is cultivated in Rajasthan, eighty percent of which occurs in western Rajasthan. Development of high yielding varieties of pearl millet has led to its increased productivity and stability largely in the regions with relatively better environments, while regions like western Rajasthan with high temperature and low rainfall still suffer from low productivity. This is because of the reason that a large number of areas under high yielding varieties (hybrids) in Rajasthan are merely 39%. The situation is worse in western Rajasthan, where farmers tend to prefer local cultivars over hybrids owing to greater risk of crop failure in poor years. Secondly, the desired production potential of these varieties could not be attained due to the incidence of downy mildew and other serious diseases. In the present paper a comparison has been made between hybrids and open pollinated varieties with respect to their grain yield and dry fodder yield production in A Zone (average annual rainfall <600 mm) and A1 Zone (average annual rainfall < 400 mm with high temperature). It has been observed that hybrids had clear grain yield as well as dry fodder yield advantage over open pollinated varieties in A zone as well as in A1 Zone. Thus, opportunity exists for increasing grain and fodder yields by growing hybrids that are adapted to this region and by bringing more area under hybrid cultivation through better seed supply and achieving high seed replacement rate.

Key Words: Pearl millet, cultivars, arid region, disease resistance, hybrids

INTRODUCTION

Bajra, the pearl millet (*Pennisetum glaucum* (L.) R. Br.) is traditionally a dryland crop, cultivated mostly in marginal environments of the arid and semi-arid regions, characterized by low rainfall, sandy soils with low fertility, where other coarse cereals such as sorghum and maize fail to produce assured yields. This crop is primarily cultivated for grain purpose, but is also valued for its stover and fodder. The crop residue/stover of pearl millet forms an important source of fodder (particularly in low rainfall regions) accounting for 40-50% of the dry matter intake and is often the only source of feed in dry months. The dual purpose nature of pearl millet offers both food and fodder security in the arid and semi-arid tropical regions of the country. Pearl millet grains have higher protein content (10.6%), more balanced amino acid profile, and also contribute about one third of iron and zinc requirements. These nutritional factors play important role in the nutritional security. A small proportion of grain is also used for poultry feed. Pearl millet grain is also gaining importance as a cheap

source of starch for making fine quality breweries (Khairwal 2003).

India is the largest producer of pearl millet, both in terms of area (9.3 m ha) and production (7.97 mt), with an average productivity of 856 kg ha⁻¹. It contributes 7.8% to the total food grain area of the country and 3.9% to the total food grain production. Rajasthan constitutes about 50% area and 42% of production of pearl millet in the country. Other principle pearl millet growing states are Maharashtra (16% area, 13% production), Uttar Pradesh (9.5% area and 16% production), Gujarat (8% area and 7% production) and Haryana (6.6% area and 13% production). Downy mildew (DM) or 'green ear' disease caused by *Sclerospora graminicola* (Sacc.) Schroet. is considered as most destructive disease of pearl millet and has assumed the status of a national problem (Arya and Kumar, 1976). In India, high yielding single cross F₁ hybrid cultivars based on A₁ cytoplasmic-nuclear male-sterility (CMS) with good tillering ability and a large number of compact, well filled ear

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heads were introduced in the mid-sixties but the desired production potential could not be attained due to the downy mildew pathogen (Singh, 1995). In a few states of India, yield losses caused by re-occurrence of DM in farmers' fields in the last 40 years led to the withdrawal of even promising cultivars (Fig. 1) that succumbed to the disease (Singh, 1994).

Pearl millet in India is grown under varying ecological environments, from very low to high productivity levels. Area under pearl millet has been categorized into two zones:

A-Zone (Dry Zone): It includes North-western states, Rajasthan, Haryana, Punjab, Delhi, Gujarat, Uttar Pradesh and Madhya Pradesh with less than 600 mm annual rainfall. This zone has sandy-to sandy loam soils. This zone contributes about 74% (6.9 m ha) to the total area under pearl millet in the country and 71% (approx 5 m t) to the total production. The average productivity of A zone is 685 kg ha⁻¹. Looking to the contribution of this zone to the area and production of pearl millet, the All India Coordinated Pearl Millet Improvement Project was shifted in 1995 from Pune in Maharashtra to Mandore (Jodhpur) in Rajasthan. Within this zone, parts of Rajasthan, Haryana and Gujarat receiving less than 400 mm of rainfall are grouped into a sub zone i.e. A1 zone. This sub-zone is highly drought prone with average annual rainfall below 400 mm, light sandy soils, and high temperatures. Average productivity of the A1 zone (Rajasthan state) is about 410 kg ha⁻¹.

B Zone (South central zone): It includes Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu with more than 400 mm annual rainfall, heavy soils and mild temperature conditions. Twenty six per cent of the pearl millet area comes under B zone and it contributes 29% (2 m tonnes) to the total pearl millet production. The average productivity of B zone is 772 kg ha⁻¹.

Production Constraints in a Zone

Low pearl millet productivity in A zone is because of three reasons namely cultivation of local cultivars (in dry areas) that have low yield potential and susceptible to diseases; abiotic stresses such as drought (varying duration and intensity) due to low erratic rainfall, high temperatures (heat) and low soil fertility (lack of nitrogen and phosphorous) with soil surface crusting and biotic stresses such as diseases like downy mildew, smut, ergot and blast etc.

Development of High Yielding Varieties and Their Spread

Work on the exploitation of heterosis first started in India in the 1950s (Rao *et al.*, 1951; Chavan *et al.*, 1955)

utilizing the protogynous flowering habit of the crop. The discovery of cytoplasmic male sterility by Burton (1958, 1965) fulfilled the need for a viable and economic method of producing pure hybrid seed on a commercial scale. The first pearl millet hybrid HB-1 was released in India in 1965 (Athwal 1965, 1966). In the 1970, not more than two hybrids of 75 days maturity were available for countrywide cultivation in India. By the year 1996, more than 50 hybrids (Govila *et al.*, 1996) and by 2006 more than 80 hybrids were cultivated in India (ICRISAT web site). This enormous cultivar diversity since 1990 has contributed not only to increased productivity, but has also halted the recurrence of any downy mildew epidemics earlier witnessed quite often on pearl millet hybrids in India. The extent of adoption of high yielding varieties in the country was 55% by 1992 (Rai *et al.*, 1996). It rose to 74.86% by 2005 (Anonymous 2005) with many states having 100% area under high yielding varieties. The situation in Rajasthan with respect to adoption of high yielding varieties is worst among the pearl millet growing states. It has only 1.75 m ha (2007-08) under high yielding varieties, which accounts for only 39% of the area under pearl millet. Farmers in western Rajasthan still prefer local cultivars over hybrids owing to greater risk of crop failure during poor years (Kelley *et al.*, 1996). Lack of availability of sufficient quantity of seed of high yielding varieties (Hybrids as well as OPVs) is another factor. Those farmers who somehow manage to plant hybrid seed first time, do second sowing with local seed after first sowing fails due to unfavorable climate or soil crusting. State government has planned to achieve seed replacement rate (SRR) of 100% by the year 2011-12, while presently the SRR of pearl millet in the state is 42%. To achieve 100% pearl millet area under high yielding varieties, quantity of seed required would be 180000 Quintals (Anonymous, 2007).

Cultivar Options

A number of pearl millet hybrids and some open pollinated varieties have been released for cultivation in arid regions; genetic differences in maturity and drought tolerance make some cultivars more suitable for dry regions. Early maturing cultivars escape terminal drought, making these more suitable for regions having extreme arid conditions, like western Rajasthan, parts of Gujarat and Haryana. The type of cultivar adoption by farmers of the arid regions however depends upon the timely and sufficient availability of seed of the cultivar (hybrid or OPV) in the market, and time and amount of rainfall received (timely and good rainfall of 30 mm received in the last week of June to the second week of July) would promote cultivation of HYVs, while late

Table 1. Hybrids and open pollinated varieties of pearl millet moderately to highly resistant to downy mildew for arid areas of Rajasthan, Gujarat and Haryana

S.No.	Cultivar	Year of release	Days to 50% flowering	Remarks
1	HHB 60	1988	44	Early maturing, tolerant to high temperature, salinity, and drought
2	HHB 67	1990	44	Earliest maturing hybrid, drought escape, suitable for multiple and intercropping system
3	HHB 68	1993	45	Early maturing, suitable for multiple and intercropping system
4	ICMH 356	1993	48	Early maturing, drought escape as well as drought tolerant, downy mildew resistant and stable yield across environments
5	RHB 121	2001	47	Early maturing, downy mildew resistant, drought tolerant, bristled panicle, tolerant to lodging
6	PB 106	2001	47	Early maturing, drought tolerant, stay green stover till harvest
7	HHB 117	2003	54	Medium maturity, downy mildew resistant, drought tolerant, stay green till harvest, tolerant to smut and lodging. Suitable for rainfed and irrigated conditions
8	GHB 538	2005	47	Early maturing, escapes drought, drought tolerant and downy mildew resistant
9	HHB 67-2	2006	42	Very early maturing, escapes terminal drought, downy mildew resistant. Higher grain yield, downy mildew resistance and better fodder quality as compared to HHB 67
10	RAJ 171	1992	53	Medium maturity, downy mildew resistant and drought tolerant, good quality fodder
11	HC 10	2000	50	Medium maturity, suitable for Haryana
12	PUSA 383	2001	48	Medium early, resistant to lodging, tolerant to moisture stress, suitable for rainfed and irrigated conditions
13	MH 169	1987	52	Medium maturity, moderate downy mildew resistant and drought tolerant
14	CZP 9802	2002	48	Early maturity, drought tolerant, downy mildew resistant and provide better quality fodder

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arrival of effective rainfall would discourage use of high yielding variety seed and sowing of local cultivar. Number of times planting is required due to failure of crop sown earlier either due to the crust formation or early season drought. This would generally lead to second or third planting with local cultivars.

A list of hybrids and open pollinated varieties, which are moderately to highly resistant to downy mildew, is presented as Table 1. These cultivars are recommended for cultivation in arid areas (Khairwal *et al.*, 2006).

Hybrids v/s Open Pollinated Varieties (OPVs)

Hybrids and open pollinated varieties possess qualities that make these suitable for different situations.

Advantages of Hybrids: High yield potential. Thus have grain yield advantage (15-30%) over OPVs; highly uniform in appearance. This morphological uniformity of hybrids instills confidence among farmers for genuineness of seed quality; highly responsive to fertilizers and management practices; and easily available in the market. All private and public sector seed agencies are producing hybrid seed; private sector favours hybrid research and development of better quality seed with more aggressive publicity.

Limitations of Hybrids: Fresh seeds are required every year; breakdown of disease resistance; and being homogeneous.

Advantages of Using an Open Pollinated Variety: Farmers can keep harvested seed from selected plants for sowing of the next crop; stable in yield; less susceptible to attack by diseases and insect pests; wide adaptability due to being heterogeneous and heterozygous (The inbuilt genetic variability acts as buffer against biotic and abiotic stresses).

Limitations of Using an OPV: Not very uniform (lack morphological uniformity), more chances of seed mixtures; not as early in maturity as hybrids; and not as high yielding as hybrids.

Comparison of Grain Yield and Dry Fodder Yield of Hybrids and Populations in A Zone (North Western States)

Grain Yield: A comparison of grain yield data for the past nine years of hybrids and populations in Advance hybrid trial (AHT) and Advance population trial (APT) conducted in A Zone locations (Fig. 1), clearly shows that hybrids produced higher grain yield over populations. The increased grain yield of hybrids over populations varied from 18% (1999, 2000) to 57% (2005) in the A Zone.

Dry Fodder Yield: Comparison of dry fodder yield of hybrids and populations in AHT and APT has the same

story as that of grain yield (Fig. 2). Hybrids excelled in dry fodder yield to populations, except during 1999, when populations recorded higher dry fodder yield over hybrids. The percentage increase in dry fodder yield of hybrids over populations varied from -7% (1999) to 21% in 2007. This denies the observation that hybrids do not produce sufficient stover.

To further assess the performance of hybrids and populations in extreme arid conditions data was considered from the same trials (AHT and APT) but from locations that fall in A1 zone locations (<400 mm).

Grain Yield Comparison from Arid Locations of AHT and APT: As is evident from the Fig. 3 hybrids recorded higher grain yield over populations during all years of these trials except during 1999, when hybrids recorded slightly less grain yield as compared to the populations. The increased grain yield of hybrids ranged from -1% (1999) to 58% (2007).

Dry Fodder Yield in Hybrids and Pop in Arid Loc (AHT & APT): Considering arid locations in AHT and APT trials, hybrids in general again recorded higher dry fodder yield as compared to the populations (Fig. 4). The increased dry fodder yield of hybrids over populations ranged between -11% (1998) to 30% (2005).

Performance of Hybrids Vs Populations in Initial/Advance Hybrid and Population in A1 Zone

To further assess the performance of hybrids and populations in extreme arid conditions (A1 Zone <400mm rainfall), a comparison of grain yield of hybrids and populations was made in the IHPT/AHPT conducted exclusively in the hyper arid locations in Rajasthan, Gujarat and Haryana.

Grain Yield: Comparison on grain yield of hybrids and populations in IHPT/AHPT (hybrids and populations both included in the same trial), revealed (Fig. 5) that here again hybrids clearly showed grain yield advantage over populations. This increased grain yield of hybrids ranged from 18% (1999) to 35% (2003).

Dry Fodder Yield: A comparison of dry fodder yield of hybrids and populations in IHPT/AHPT revealed that under extreme arid conditions, populations gave slightly higher dry fodder yield as compared to hybrids (Fig. 6). Populations recorded -5% to 14% higher dry fodder yield over the hybrids. Populations recorded maximum dry fodder yield in the year 2001 followed by in 2007. However, it was observed that out of nine years it was only during the year 2001 and 2007 that populations recorded significantly higher dry fodder yield as compared to the hybrids. Thus, in general hybrids gave almost same dry fodder yield as that of populations.

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The above comparisons clearly showed that hybrids had almost always recorded significantly higher grain yield over populations in A Zone (north western states). Hybrids also recorded significantly higher dry fodder yield over open pollinated varieties in A zone (>400 mm rainfall). Hybrids recorded higher or almost equal dry matter yield over populations even in A1 Zone i.e. extreme arid locations having average annual rainfall less than 400 mm. This is when no specific efforts have been made to develop dual-purpose hybrids. Development of dual-purpose hybrids capable of producing higher biomass can lead to hybrids producing higher dry fodder yield even under extreme arid conditions. The present data thus suggests that hybrids are the solution for enhancing grain yield as well as dry fodder yield productivity of the arid as well as hyper arid areas.

The main cause of low productivity of Rajasthan is that only 39% of its area under pearl millet is cultivated with high yielding varieties, while the remaining 61% is still cultivated with low yielding local cultivars, leading to the

lowest pearl millet productivity. The situation is still worse if arid western Rajasthan is considered which has about 80% of the total area under pearl millet in Rajasthan. This poor coverage of area under high yielding varieties is primarily due to lack of sufficient supply of the hybrid/OPV seed to cover the entire pearl millet area in A zone, and secondly the need of sufficient number of hybrids suitable for extreme arid conditions giving choice to farmers to choose.

Here comes the role of private and public sector seed producing agencies to gear up their seed production machinery so that SRR of 100 % can be achieved in pearl millet, which at present is 42%. For saturating arid regions with HYVs seed, at least for OPVs seed production, seed village concept can be utilized for seed production and its distribution, using services of the NGOs and KVKs, for immediate effect and till hybrids seed is made available in sufficient quantity for saturating area under pearl millet in arid regions.

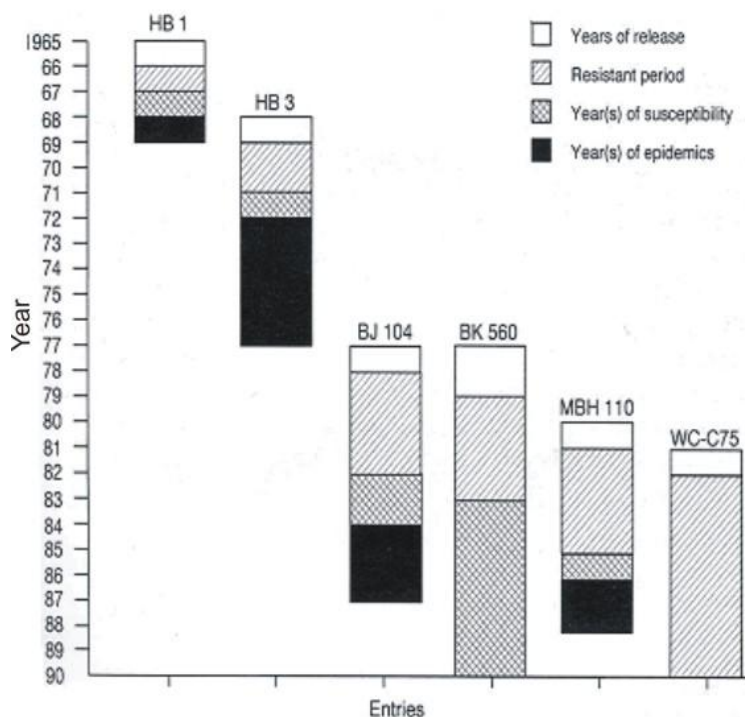


Figure 1. Graphical presentation of six popular cultivars of pearl millet grown in India showing relative susceptibility and resistance periods, 1965-90. (Source: Singh *et al.*, 1997).

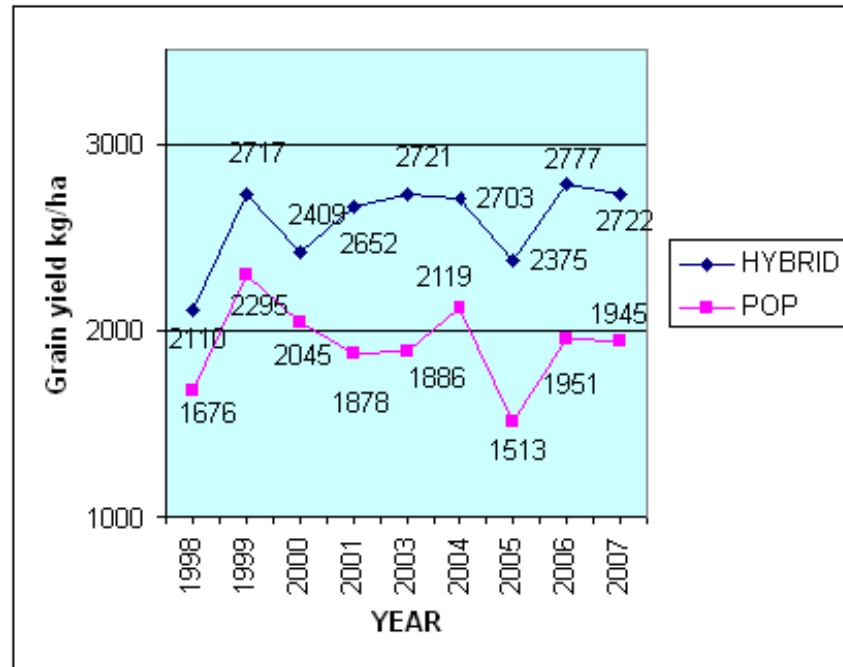


Figure 2. Grain yield (in Kg ha⁻¹) in AHT and APT in A Zone

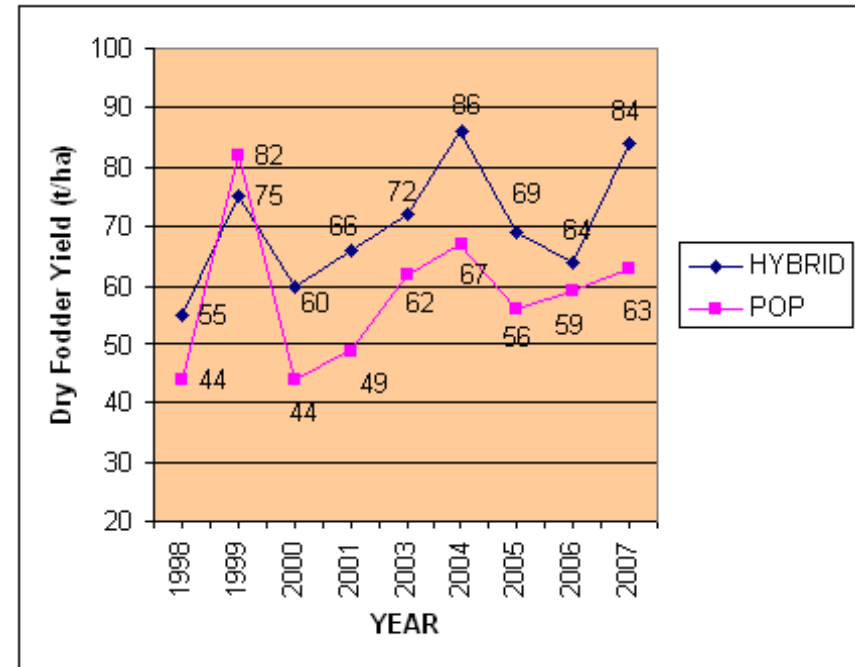


Figure 3. Dry fodder yield in AHT and APT A zone.

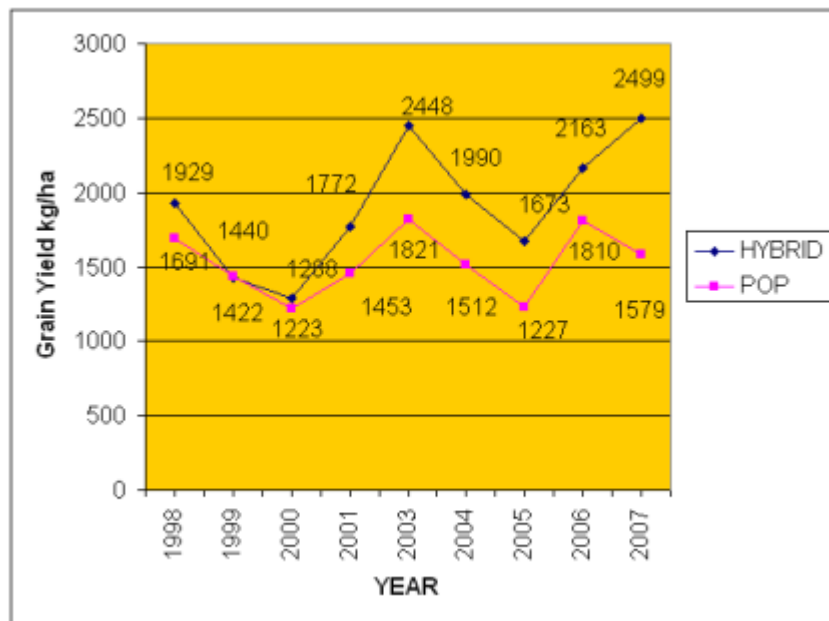


Figure 4. Grain yield of hybrids in AHT and POP in APT at A1 location

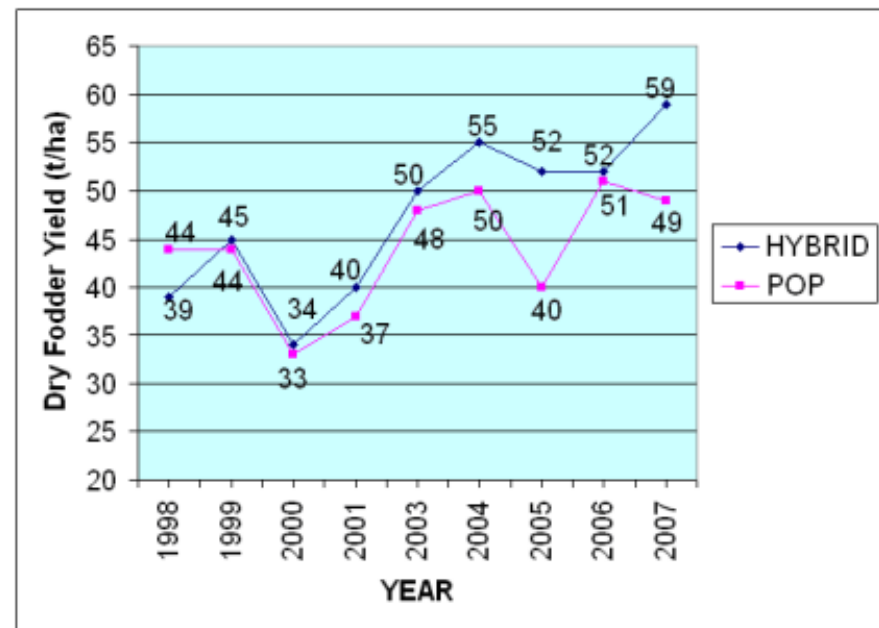


Figure 5. Dry fodder yield in AHT and APT A1 locations

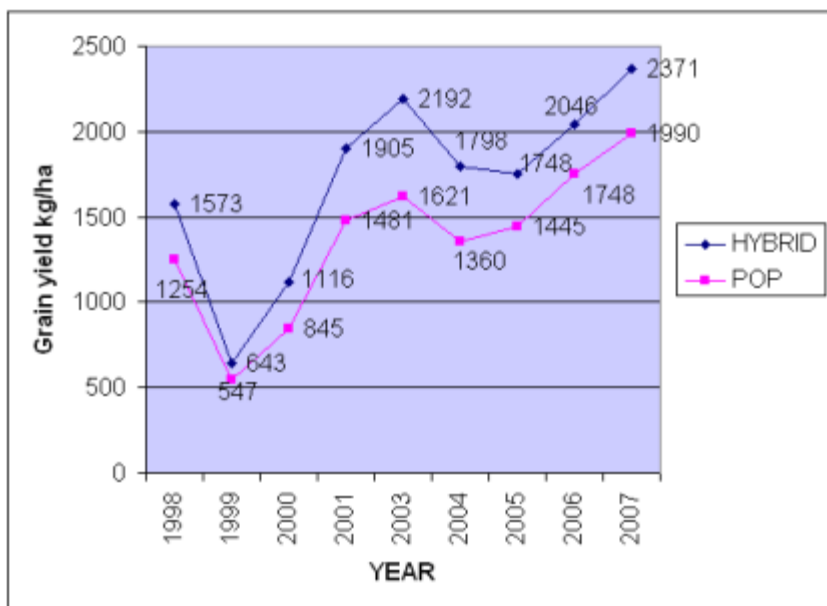


Figure 6. Mean grain yield (in Kg ha⁻¹) A1 zone (IHPT/AHPT)

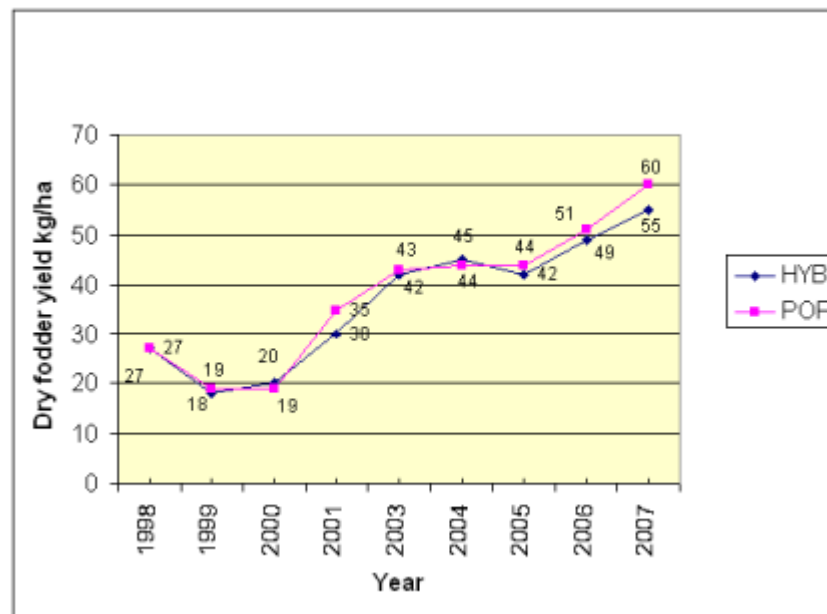


Figure 7. Mean dry fodder yield of hybrids versus populations in A1 zone (IHPT/ AHPT)

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