

Shalimar Maize Hybrid 4, a Most Promising Hybrid for High Altitude Ecologies of Kashmir Valley

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Authors' contributions

This work was carried out in collaboration among all authors. Authors MAA, ABS, SAW and FAS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SN and NAT managed the analyses of the study. Authors ZAD and AAL managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2020/v39i2730932

Editor(s):

(1) Dr. Nhamo Nhamo, Zimbabwe Open University, Zimbabwe.

Reviewers:

(1) Henrique Pozebon, Universidade Federal de Santa Maria, Brazil.

(2) Benjamin Valladares Carranza, Autonomous University of the State of Mexico, Mexico.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/60187>

Original Research Article

Received 18 June 2020
Accepted 23 August 2020
Published 15 September 2020

ABSTRACT

Maize is one of the most important cereal crops of Kashmir Valley where it serves as a source of food, feed, fodder and industrial raw material, providing enormous opportunity for crop diversification, value addition and employment generation. However, the average productivity of maize in Kashmir Valley is quite low (1.5 t ha^{-1}) when compared to the national productivity (2.5 t ha^{-1}). The development, dissemination and adoption of high yielding, early maturity, cold tolerant maize hybrids can serve as the most economical, effective and coherent approach to contribute significantly towards increasing maize production in Kashmir Valley. A single cross hybrid SMH4 (Shalimar Maize Hybrid 4) has been developed to enhance the maize productivity in high altitude agro-ecologies of the Valley. SMH4 possesses very high yield potential of about $7.0\text{-}8.2 \text{ t ha}^{-1}$ compared to $2.5\text{-}4.0 \text{ t ha}^{-1}$ as realised by the predominantly grown landraces in hilly agro-ecosystems. The hybrid revealed the grain yield superiority of about 23.61% and the stover yield superiority of about 15.77% over the commercial check viz., Shalimar maize Hybrid 1. The variety is resistant to Turcicum leaf blight and common rust, besides showing resistance to stem borers and

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cut worms. SMH4 has a very good acceptability by farmers for its high yield potential (both grain and fodder), better seedling vigour and early maturity. SMH4 with the traits like cold tolerance and early maturity can play a potential role in enhancing the economy of maize growers under high altitude ecologies of Kashmir Valley. The development, upscaling and mass adoption of SMH4 in temperate agro-ecologies will lead to socio-economic upliftment of small and marginal farmers through increase in production, productivity and farm profitability.

Keywords: Kashmir valley; Shalimar maize hybrid 4; yield; disease resistance; cold tolerance.

1. INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop of the world after rice and wheat. The crop ranks first in production and productivity, and possesses wider adaptability towards diverse agro-climatic conditions [1]. It is the major source of food, feed, fodder and industrial raw material, and provides enormous opportunity for crop diversification, value addition and employment generation [2]. In India, maize ranks third in area amongst the cereals and is grown over an area of about 9.4 million hectares with the production of 23 million tons and productivity of 2.5 tons per hectare. Its contribution to the country's total food grain production is about 9 per cent [3]. In Jammu and Kashmir, maize is the second most important cereal crop after rice, cultivated over an area of about 0.30 million hectares with annual production of 0.53 million tons. Maize in Jammu and Kashmir is grown as *Kharif* season crop, mostly on marginal lands and hilly terrains and about 85% of the cropped area is rainfed. Kashmir Valley (longitude 73.0-74.2°E and latitude 33-34°N) is agro-climatically a typical temperate region where maize is grown as a sole crop or intercropped with beans. The average productivity of maize in Kashmir Valley is quite low (1.5 t ha⁻¹) when compared to the national productivity (2.5 t ha⁻¹).

The demand for maize in the Kashmir Valley has to be met either by technological interventions or by means of horizontal increase in the production. Although, there seems little scope for area expansion, the technological interventions need to be adopted to increase the productivity levels. Development of high yielding varieties through conventional and biotechnological interventions would be an immediate solution in bridging the gap between production and demand. As part of the overall efforts in accelerating maize production in Kashmir Valley, the breeders are aiming at the development of high yielding, widely adapted, fertilizer-responsive, biologically efficient varieties that are highly tolerant to the vagaries of weather and

prevailing diseases/pests. Thus, there has been considerable emphasis on the use of hybrid maize technology to improve the productivity of maize crop in the Valley. The release of high yield hybrids along with other technological developments has nearly doubled the average yield of maize in J&K in the last one decade.

Exploitation of heterosis through the development of high yielding maize hybrids has gradually replaced the low yielding maize populations at a faster rate in favourable maize growing ecologies. However, the marginal and hilly terrains of the Valley could not be benefitted much by these high yielding hybrids. These areas are characterized by short growing seasons, low atmospheric temperature, cold irrigation water and insufficient solar radiations, thereby setting the limitations for crop production. In higher altitudes, the temperatures are generally mild even during the summer season, leading to prolonged growing periods and delayed harvesting [4]. Early maturing land races with a degree of cold tolerance and very low yield potentials are mainly cultivated in these ecologies. Moreover, the maize crop in these regions is subjected to enhanced incidence of biotic stresses especially *Turcicum* leaf blight caused by *Exserohilum turcicum* and common rust caused by *Puccinia sorghi* [5]. Along with the reduction in grain yield, the biotic stresses cause immense damage to crop straw, the only source of fodder in Kashmir Valley during the winter season [6]. The yield losses due to these biotic stresses has been reported to be 12-91 per cent [7,8].

The development, dissemination and adoption of early maturing, cold tolerant maize hybrids can serve as the most economical, effective and coherent approach to contribute significantly in increasing maize production under high altitude ecologies of Kashmir Valley [9]. With this background, a single cross maize hybrid viz., Shalimar Maize Hybrid 4 (SMH4) has been developed to replace the low yielding land races

and to achieve food, profitability and livelihood security under higher altitudes of Kashmir Valley. In this study, SMH4 was evaluated for various traits of economic importance. The variety was observed to show very high yield potential and is recommended for the altitudes ranging from 1800-2250 m amsl. The variety is resistant to Turcicum leaf blight and common rust besides showing resistance to stem borers and cut worms. SMH4 has very good acceptability among farmers for its high yield potential (both grain and fodder), better seedling vigour and early maturity.

2. MATERIALS AND METHODS

Shalimar Maize Hybrid 4 (SMH4), a single cross hybrid was developed by Mountain Crop Research Station (MCRS) Sagam of SKUAST-K after crossing inbred line SMI31 (as female parent) with inbred line SMI462 (as male parent). SMI31 and SMI462 have been derived from CML31 and CML462 respectively, after selection and stabilization under high altitude conditions of Kashmir Valley. SMI31 is a short statured line with sparse tassel, good cob traits and better seed setting. SMI462 possesses medium statured plant type with dense tassel, producing abundant pollen for prolonged durations.

The hybrid was evaluated in a series of research, coordinated and minikit trials along with standard checks. During *Kharif* seasons of 2018 and 2019, SMH4 was evaluated under the research trials at Mountain Crop Research Station (MCRS) Larnoo (located at latitude 33° 37' N, longitude 75° 22' E and an altitude of 2286 m amsl) for various yield and agronomic attributes. Likewise, to evaluate its performance in the farmer's fields, SMH4 was tested under Minikit trials during the *Kharif* seasons of 2018 and 2019. The Minikit testing in the farmer's fields was carried out in collaboration with State Department of Agriculture, covering all the districts of Kashmir Valley. SMH4 was tested under all India Coordinated Maize Improvement Programme in the North Hill Zones of India during the *Kharif* seasons of 2015 and 2016 to assess the performance of the variety across different locations. The protein profiling and DNA fingerprinting of the variety was carried out at Biotechnology Laboratory of SKUAST Kashmir. DNA was extracted from the leaves of 15 days old seedlings according to CTAB method. The DNA fragments were PCR-amplified prior to electrophoresis.

The hybrid was evaluated at MCRS Larnoo under various agronomic management practices viz., different fertilizer and spacing levels to devise the most effective combination for optimum yield returns. The variety was screened against various insect pests viz., stem borers (*Chilo partellus*), beetles (*Phyllotera* spp), cutworms (*Agrotis* spp) and aphids (*Rhopalosiphum maidis*) during *Kharif* seasons of 2017 and 2018 following the Standard Evaluation System of CIMMYT [10]. The scoring was carried out on the basis of detection of damage and not on the basis of detection of individuals. The variety was also screened for resistance towards Turcicum leaf blight (caused by *Exserohilum turcicum*) and common rust (caused by *Puccinia sorghi*). Disease rating scale of 1-9 was used for scoring the disease reaction [11]. The genotypes showing disease intensity of <11.11% were considered as highly resistant (HR), 11.12-22.22% as resistant (R), 22.23-44.44% as moderately resistant (MR), 44.45-66.66% as moderately susceptible (MS) and 66.67-99.99% as susceptible (S). Disease and pest assessment scores were recorded from 10 randomly selected plants from each plot at 25 days intervals, starting from 20 days after sowing. No insecticide/fungicide sprayings were carried out at any stage of the crop growth.

3. RESULTS AND DISCUSSION

Most of the improved varieties of maize developed in India are suitable for favourable production ecologies. Almost all the major maize growing ecologies of Kashmir are typically marginal, where short growing seasons, low atmospheric temperature, cold irrigation water and insufficient solar radiations, besides diseases like Turcicum leaf blight and common rust serve as the major challenge for crop production. Under these ecologies, the maize crop is usually sown in the month of April and seeds remain un-germinated for weeks together due to the unexpected fall in temperature. SMH4 with the traits like cold tolerance, early maturity and disease resistance can play a potential role in enhancing the economy of maize growers under high altitude conditions of Kashmir Valley. The hybrid possesses very high yield potential of about 7.0-8.2 t ha⁻¹ compared to 2.5-4.0 t ha⁻¹ as realised by the predominantly grown landraces in hilly ecologies of Kashmir Valley. It has been estimated that if the productivity gets enhanced from 1.5 to 3.0 t ha⁻¹, an additional 150 thousand tons can be produced from high altitude rainfed ecologies of the Valley [12].

In research trials, the mean performance of SMH4 for grain yield over years and locations was 8.23 t ha⁻¹. The hybrid revealed the grain yield superiority of about 23.61% and the stover yield superiority of about 15.77% over the commercial check viz., Shalimar Maize Hybrid 1 (Table 1). The results of minikit tests in farmers' fields revealed that the average yield of SMH4 over years and locations was 6.63 t ha⁻¹ with an overall superiority of about 15.0% over the commercial check (Fig. 1). The results of multi-location trials for SMH4 conducted in collaboration with All India Coordinated Maize Improvement Project for North Hill Zone of India revealed that the variety produced an average yield of 5.56 t ha⁻¹ with highest yield of 8.60 t ha⁻¹ at Bajaura Himachal Pradesh (Fig. 2).

Timely sowing with adequate soil moisture at critical crop growth stages (like tasselling, silking and grain filling) are the prerequisites to exploit the maximum heterotic potential of this variety. The soil should be applied with sufficient quantity of organic manures and fertilizers. The results of various agronomic manipulations over years and locations revealed that SMH4 realised the maximum yield potential at the planting geometry of 60 × 20 cm² accommodating around 83500 plants ha⁻¹ of land. The treatment also involves the application of 75, 50, 25 kg of N, P₂O₅, K₂O, respectively to per hectare of land, besides using 15 t ha⁻¹ of well rotten FYM. In this treatment, half of the N fertilizer was applied at the time of planting and rest half at 30–35 days after that. The conjunctive use of organic manure and chemical fertilizers can augment the nutrient use

efficiency and also enhance the productivity of maize [13]. Likewise, yield response of SMH4 was maximum when the crop was sown in 2nd week of April with seed rate of 20 kg ha⁻¹ for line sowing and 30 kg ha⁻¹ for broadcasting. However, under high altitude rainfed ecologies farmers generally go for broadcasting on scattered, undulating and small land holdings. Moreover, farmers apply higher seed rates to avoid crop failures and to get more stover yield which serves as a main source of fodder during winter months.

The major biotic stresses for maize cultivation under high altitude conditions of Kashmir Valley include various diseases and insect pests. Turicum leaf blight and common rust causes enormous damage to maize crop and the yield losses range from 24 to 91 per cent [7]. The disease epidemics at an early stage cause premature death of blighted leaves which lose their value even as a fodder [14]. The use of resistant cultivars is the most effective, efficient, safe and practical method of obviating loss in crop yield. Inherent resistance or tolerance of crop plants to pathogens is the safest, economical and eco-friendly disease management approach to cope up with the problem [15]. SMH4 was observed to show resistance towards Turicum leaf blight and common rust. The turicum leaf blight and common rust disease intensity on SMH4 was recorded to be 14.6% and 12.2% respectively, with a disease grade of 2 in 1-9 evaluating scale (Fig. 3). Of the various insect pests of maize, SMH4 shows resistance towards stem borers and aphids (Fig. 4).

Table 1. Yield performance of SMH4 in research trials over years and locations

Year	Grain yield (t ha ⁻¹)						Per cent increase over the check
	SMH4			SMH1			
	MCRS Larnoo	MRCFC Khudwani	Mean	MCRS Larnoo	MRCFC Khudwani	Mean	
2014	8.66	8.33	8.50	7.58	6.57	7.07	20.12*
2015	8.40	8.02	8.21	7.12	6.42	6.77	21.25*
2016	7.94	7.75	7.85	6.25	6.06	6.16	27.48*
2017	8.56	8.13	8.35	7.15	6.14	6.65	25.61*
Mean	8.39	8.06	8.23	7.02	6.30	6.66	23.61*
Stover yield (t ha ⁻¹)							
2014	15.43	15.13	15.28	14.00	13.00	13.50	13.22*
2015	14.72	14.46	14.59	13.15	11.86	12.51	16.72*
2016	14.11	13.81	13.96	12.48	11.32	11.90	17.28*
2017	15.05	14.74	14.90	13.42	12.22	12.82	16.18*
Mean	14.83	14.54	14.68	13.26	12.10	12.68	15.77*

* indicates that SMH4 has significantly higher yield over SMH1 (p= 0.05)

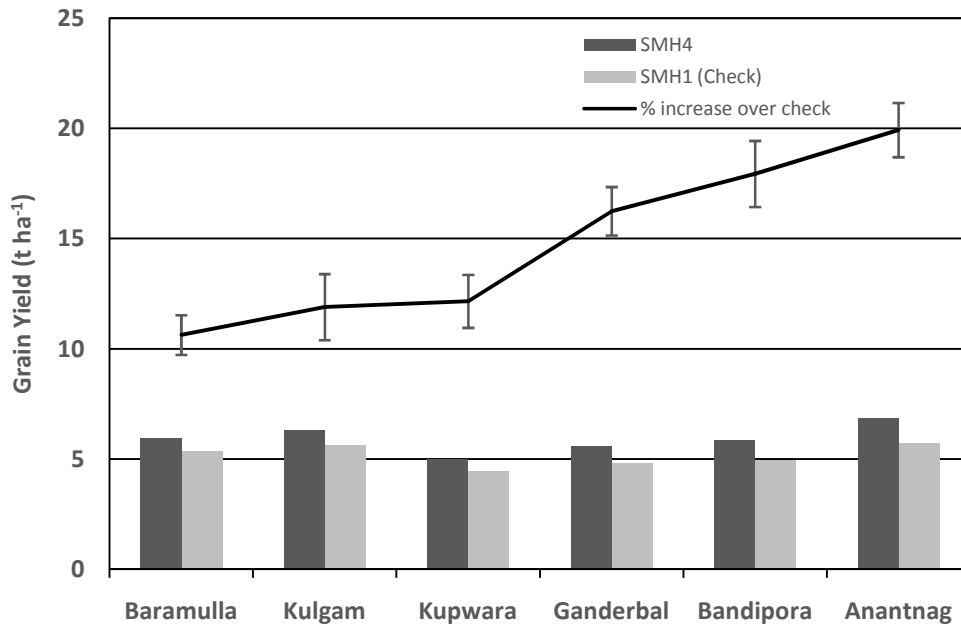


Fig. 1. Grain yield performance of SMH4 in minikit trials

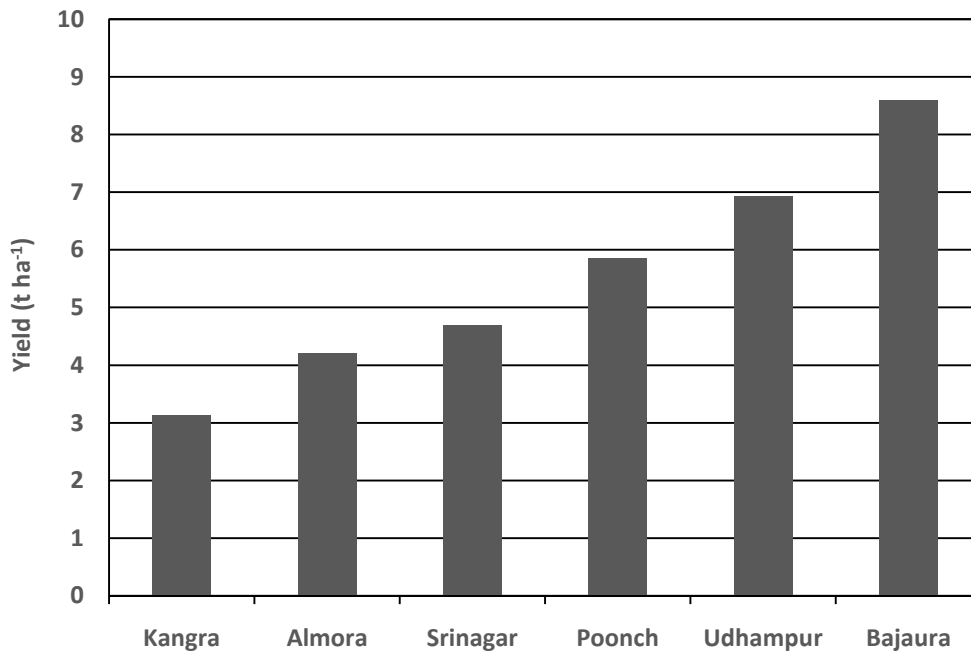


Fig. 2. Grain yield performance of SMH4 in All India coordinated research trials

SMH4 has been characterized for various agromorphological traits. The plant height of SMH4 ranges from 255-265 cm with ear placed at the mid position (100-120 cm from the ground level). The cob is long conical with semi flint yellow grains (Fig. 5). The variety has been recommended for cultivation under high altitude rainfed temperate ecologies ranging from 1800 to 2250 m amsl. It matures in 135 to 140 days at an

altitude range of 1800 to 2000 m amsl and in 150 to 155 days at an altitude range of 2000 to 2225 m amsl. The grain yield potential in farmer's fields range from 7.0 to 8.0 t ha⁻¹. The variety retains its greenness even upto maturity which improves its fodder quality. The benefit cost ratio was estimated by calculating the total cost of cultivation and the net returns of SMH4 per hectare of land. The benefit/cost ratio value ha⁻¹

of SMH4 was 2.27 which is higher than the check varieties (Table 2).

Molecular screening of SMH4 was carried out using 49 markers. The markers umc1859, bnlg1138, bnlg1904, bnlg1605, umc2210, bnlg1136 and umc1568 revealed clear

polymorphism between the parental lines (Fig. 6). These markers amplified different sized alleles and produced multi-locus profile that may be used to characterize the hybrid (Table 3) [16]. Besides, markers like bnlg1904, bnlg1740 and bnlg198 can be used to discriminate SMH4 from SMH1 (a check variety).

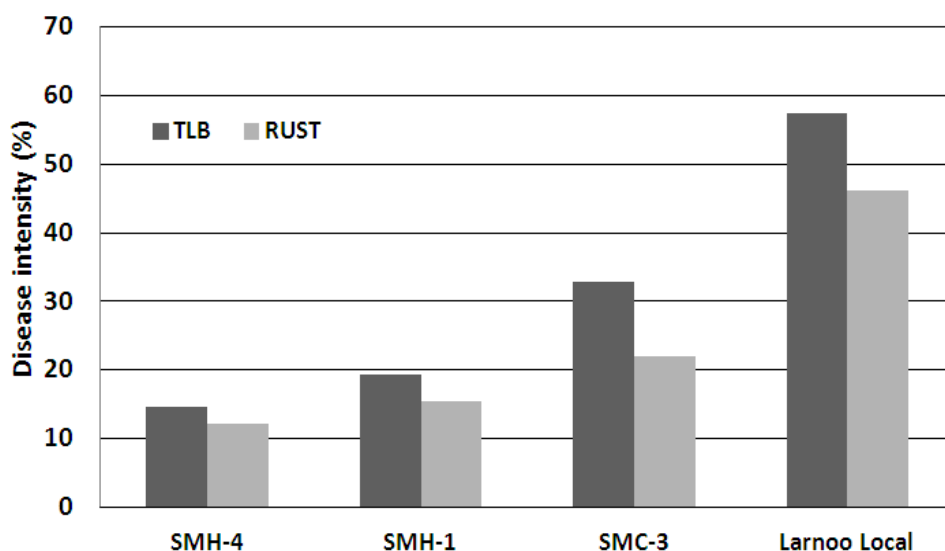


Fig. 3. Diseases intensity of SMH4 in comparison to other varieties

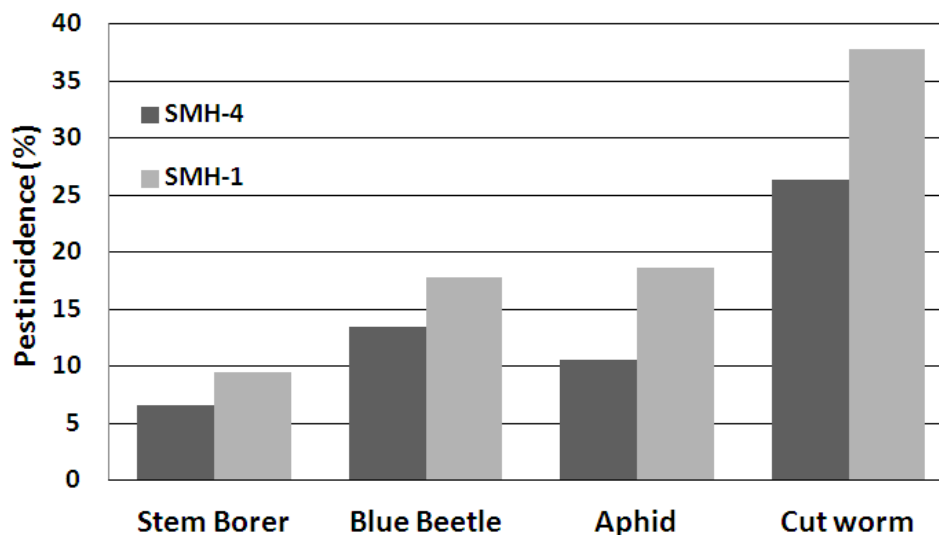


Fig. 4. Pest incidence (%) of SMH4 in comparison to the check variety

Table 2. Economic analysis of SMH4 and the check varieties for grain and straw yield

Variety	Cost of cultivation (ha ⁻¹)	Gross returns (ha ⁻¹)	Net returns (ha ⁻¹)	B/C ratio (ha ⁻¹)
Shalimar Maize Hybrid-4	48570	159000	110430	2.27
Shalimar Maize Hybrid-1	48570	140600	92030	1.89
Larnoo Local (local check)	48570	108000	59430	1.22



Fig. 5. Agro-morphological traits of Shalimar Maize Hybrid 4

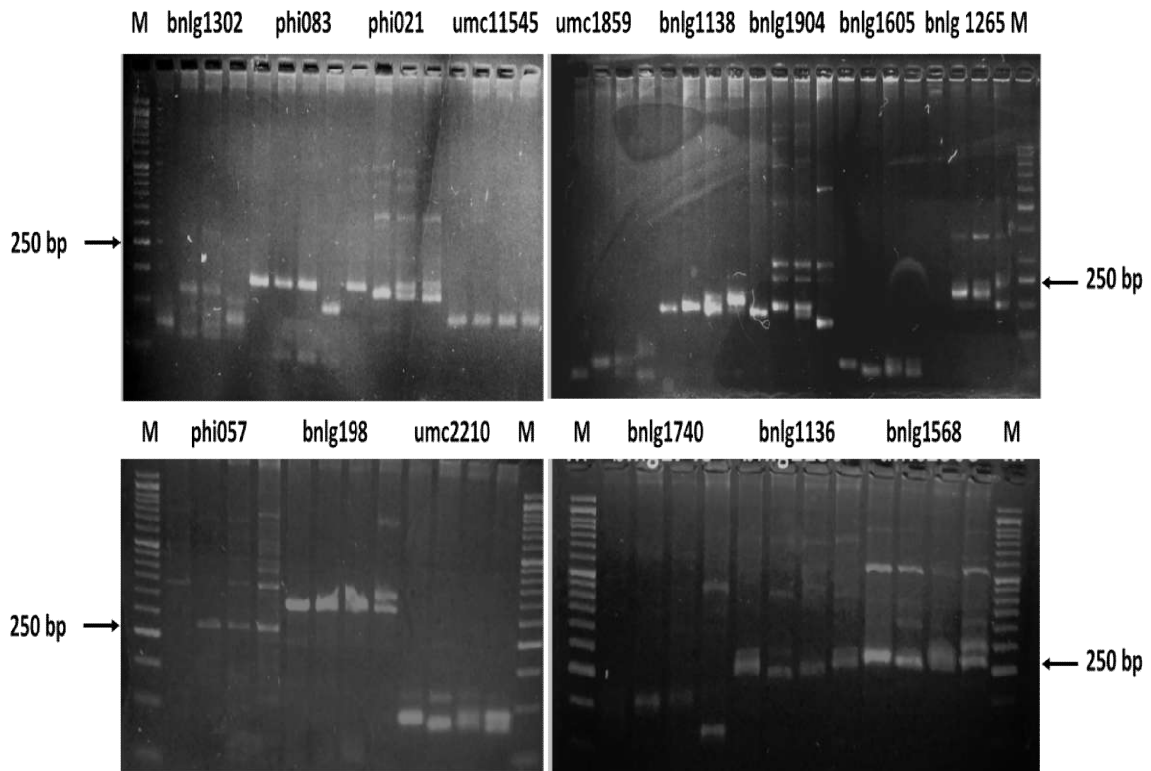


Fig. 6. DNA fingerprinting of SMH4 along with its parental lines and check (arranged as P1, P2, SMH4 and SMH1)

Table 3. DNA fingerprinting of SMH4

Name of the Marker	SMI31 (Inbred Parent 1)	SMI462 (Inbred Parent 2)	SMI31 x SMI462 (SMH4)	Shalimar Maize Hybrid 1
umc1859	100	125	100/125	100/125
bnlg1138	200	210	200/210	200/210
bnlg1605	100	80	100/80	100/80
phi057	325	250	325/250	325/250
umc2210	190	175	190/175	190/175
bnlg1136	200	180	200/180	200
umc1568	225	210	225/210	250/210
bnlg1904*	200	210	200/210	175
bnlg198**	350	350	350	350/400
bnlg1740**	200	200	200	150

Figures refer to the allelic size (bp) of the amplified locus; *The marker was polymorphic between two inbred parents and also discriminated the SMI31 x SMI462 from Shalimar Maize Hybrid 1; **The markers were monomorphic between two inbred parents, however, discriminated the SMI31 x SMI462 from Shalimar Maize Hybrid 1

4. CONCLUSIONS

Development of maize hybrids (like SMH4) with farmer preferred traits like early maturity, cold tolerance, resistance to various biotic stresses and suitable for rainfed mountain agro-ecosystems has the potential to boost the maize industry under such ecologies. The development, upscaling and mass adoption of SMH4 in temperate agro-ecologies will lead to socio-economic upliftment of small and marginal farmers through increase in production, productivity and farm profitability.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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