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RESEARCH ARTICLE

IDENTIFICATION OF PRO-VITAMIN A MAIZE GENOTYPES FOR NEPAL

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ABSTRACT

Areas where maize is consumed as staple, consumers are suffering from vitamin A deficiency. To tackle this problem, pro-vitamin A maize genotypes both open-pollinated and hybrid types received from International Maize and Wheat Improvement Centre were evaluated at National Maize Research Program, Rampur; Horticulture Research Station, Dailekh; Agriculture Research Station, Surkhet and in farmers' field at Sandhikharka in Arghakhanchi district during summer season of 2014/015. Experiments were consisted of 25 genotypes and planted in rendomized complrte block design with three replications. Poshilo Makai-1 and RML-86 x RML-96 were used as checks. Highly significant differences among the tested genotypes for grain yield were recorded. Likewise, highly significant differences between the locations and significant differences for location by genotypes for grain yield were observed. Results when combined over locations, genotypes namely normal hybrid RML-86 x RML-96 produced the highest grain yield (7030 kg ha^{-1}) followed by pro-vitamin A genotypes CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-3-B (6808 kg ha^{-1}), CML451-B-B/CLHP0002-B//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B (6382 kg ha^{-1}), CML496-B/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B (6375 kg ha^{-1}), CML486/CLHP0003-B// (CML329/ CML20)F2-3-4-B-B-B-B-B (6201 kg ha^{-1}), CML551/CLHP0002-B//(P147-F2#152-S7/CML323)-F2-B-1-1-1 (6111 kg ha^{-1}) and CLHP0003-B/CLHP0005-B//CLHP0352 (6095 kg ha^{-1}). Days to flowering, and plant and ear heights of these selected genotypes were at par with previously released improved maize varieties and thus fit into farmers' existing cropping pattern.

INTRODUCTION

More than 250 million of the world's children suffer from vitamin A deficiency (Fiedler, 2000). It leads to the deaths of over 800,000 women and children each year. Vitamin A deficiency is estimated to be responsible for nearly one-fourth of global child mortality from measles, diarrhea and malaria and for a fifth of all-cause of maternal mortality (Gottlieb). Its deficiency retards growth, increases risk of diseases, can cause reproductive disorders, blindness, night blindness, dryness of outer lining of eyeball, corneal ulceration, poor bone growth, skin changes and increases risk of infections like measles (Pfeiffer and McClafferty, 2007; Chataut, 2017; Joyce Maru , 2017). The majority of the Nepalese population is engaged in agriculture. In Nepal, about 13% of the population is considered to be moderately to severely food insecure, and 35 out of 75 districts are classified as food insecure with respect to food grains (MoAD, 2017).

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Poverty is still widespread (25% of the population). ADS (2014) targets to reducing food poverty from 24 to 5%, and annual agricultural growth from 3 to 5% as compared to base year 2010 after 20 years. It is reported that children in rural areas are more likely to be stunted (42%) than those in urban areas (27%) (Dolf, JH te Lintelo et al., 2014). ADS (2014) aims to reduce stunting, under-weight, wasting and women with low body mass index (BMI), respectively from 41.5, 31.1, 13.7 and 18% (base year 2010) to 8, 5, 1 and 5%, by its completion. Micronutrient defficiency or so called "hidden hunger" becomes less visible and usually begins to appear when the condition is severe and has already led to serious health problems. This occurs when people do not have access to micronutrient-rich foods such as fruits, vegetables, animal products and fortified foods (Thompson and Amoroso, 2011). In the 1990s, 2–8 percent of preschool-aged Nepali children experienced severe vitamin A deficiency or xerophthalmia, associated with blindness and risk of child death. Another target group for vitamin A interventions is pregnant and breast-feeding women (Gottlieb). Each year in Nepal, vitamin A deficiency is responsible for the deaths of 9000 children and for 2500 children becoming permanently blind as reported by

Fiedler (2000) and was reduced to the deaths of approximately 6,900 children by 2012 (World Bank). In 1993, the government of Nepal initiated the National Vitamin A Programme by distributing high-dose vitamin A capsules to all children 6 to 60 months of age during twice-yearly campaigns (Fiedler, 2000). This program prevented blindness in approximately 2,000 children each year, and was found to reduce under-five mortality in Nepal by about half between 1995 and 2000 (Gottlieb). Agriculture mainly focuses on production increment with little concern for nutritional or health-promoting qualities. Nutritionists emphasize unsustainable medical approaches to solve malnutrition problems by using supplements and fortification of food (Welch, 2005). For many people in Nepal, maize is a subsistence crop. Scientists have developed pro-vitamin A rich maize genotypes that provide not only increased levels of pro-vitamin A but also higher yields to farming communities for food security and to combat vitamin A deficiency. Beta-carotene contained in pro-vitamin A converts into vitamin A when maize is consumed, thereby boosting the immune system (CGIAR, 2012). Maize is the predominant staple food in mid and high hills of Nepal. Therefore, the introduction of a provitamin A maize could significantly reduce vitamin A deficiency, especially in rural maize producing communities.

MATERIALS AND METHODS

Genetic Materials

An experiment consisting of 23 pro-vitamin A maize genotypes and two checks (normal maize) was conducted at National Maize Research Program (NMRP), Rampur; Horticulture Research Station (HRS), Dailekh; Agriculture Research Station (ARS), Surkhet and at Sandhikharka in Arghakhanchi district during summer season of 2014/015. Among the pro-vitamin A genotypes three and twenty were three-way crosses and open-pollinated varieties, respectively. A single cross hybrid (RML-86 x RML-96) and an open-pollinated variety (Poshilo Makai-1) developed by NMRP were used as checks.

Experimental Sites

The climate of NMRP Rampur is humid and subtropical with cool winter (2-3^{0}C) and hot summer (43^{0}C). The annual precipitation is over 1500 mm with a distinct monsoon period (>75% of annual precipitation) from mid-June to mid-September. The soil texture of NMRP Rampur is sandy loam having moderately acidic pH value of 5.43 with high organic matter (3.95%) and medium level of nitrogen content (0.15%). High level of phosphorus (33.76 ppm) and potassiun (145.29 ppm), very low level of boron (0.17 ppm) and medium level of zinc (1.58 ppm) is available in the soil. ARS Surkhet has subtropical climate with average annual precipitation of 1747 mm, of which 80% occurs between June and September. Temperature ranges from 7.9^{0}C to 36.9^{0}C in the month of January and June, respectively. The soil of the station is sandy loam in texture and moderately acidic in reaction with pH value from 5.3-5.8. The soil texture of HRD Dailekh is loam having very acidic pH value of 5.17 with medium level of organic matter (2.88%) and nitrogen content (0.12%). Similarly, very high level of phosphorus, high level of potassiun, low level of boron and low level of zinc is available in the soil 109.80, 178.90, 0.65 and 0.89 ppm, respectively.

Experimental Design and Cultural Practices

Experiments were conducted in rendomised complete block design with three replications. Plot size was four meter long two rows. Row-to-row and plant-to-plant spacing was maintained at 75 cm and 25 cm, respectively. Two seeds per hill were planted and thinned to single plant during first weeding. Fertilizer was applied @120:60:40 N:P:K kg^{-ha}. Half of the N and full dose of P_2O_5 and K_2O were applied as basal dose. The remaining half dose of N was applied in two splits at knee-high and pre-tasseling/silking stages. Most of the agronomic practices were carried out as per recommended. Grain yield was adjusted to 80% shelling recovery and 15% moisture level.

Data Recording and Measurements

Grain yield, days to tasseling and silking, plant and ear heights were recorded. Grain yield was estimated using formula given below by adjusting the grain moisture at 15% and converted to the grain yield kg per hectare.

$$\text{Grain yield (kg/ha)} = \frac{\text{F.W. (kg plot}^{-1}\text{) x (100-M.C.) x SP x10,000}}{\text{85 x Net harvested area (m}^2\text{)}}$$

Where,

F.W.= Fresh weight of harvested ears in kg per plot
M.C.= Grain moisture content in percent at harvest
SP= Shelling percent
85= Grain moisture adjusted to 15%

Plant height was measured in cm as the distance from the base of the plant to the top of the plant from where tassel starts branching. It was measured as an average of the randomly taken five plants. This was recorded just prior to harvesting. Ear height was also measured in cm at the same time from those plants which were used for plant height. It is the distance from base of the plant to the uppermost ear bearing node. The upper ear is the main ear because during the growing season only the upper 1 or 2 ears are able to develop completely, except in "prolific" varieties. These varieties could play an important role in breeding for higher yield (Motto and Moll, 1983).Days to tasseling and silking were recorded counting the days from seeding to days when tassels and silks emerge from 50% plants, respectively. Plant stand at harvest is the total number of plants in each plot from net harvested area at harvesting time regardless of ear bearing or not ear bearing plant.

Statistical Analysis

The statistical analysis was done using computer software MSTATC version 1.2 (Freed, 1990) applying 5% level of significance.

RESULTS

Grain Yield

Grain yield differences among the tested genotypes were recorded highly significant. Genotypic (G) performance across the locations was also evident. Significant variations were recorded for genotype by environment (G x E) interactions which shows the location specific nature of the tested genotypes.

In Arghakhanchi, experimental mean grain yield (7732 kg ha^{-1}) was highest among the sites. Grain yield ranged from 5964 (CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-2-B) to 9108 kg ha^{-1} (CLHP0003-B/CLHP0005-B//CLHP0452). Other high yielding genotypes were CLHP0003-B/CLHP0005-B//CLHP00322 (9084 kg ha^{-1}), CML486/CLHP0003-B//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B (8969 kg ha^{-1}), Local check RML-86 x RML-96 (8872 kg ha^{-1}) CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B (8818 kg ha^{-1}) and CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-1-B (8775 kg ha-1) , respectively and statistically were at par.Ten genotypes produced grain yield more than 8000 kg ha^{-1}.

Other genotypes namely CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-4-B (4484 kg ha^{-1}) and CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-1-B (4376 kg ha^{-1}) were statistically at par for this trait with high yielding genotype. At NMRP Rampur, Local check RML-86 x RML-96 (8273 kg ha-1) out yielded others and followed by CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-3-B (7000 kg ha^{-1}), CML486/CML327/ /(CML226/ D888/CML226/CATETO)F2-B-1-1-B-B (6695 kg ha^{-1}) and CML451-B-B/CML323//(AC-S 99MBRY-1)-B-12-2-1-B-B (6578 kg ha^{-1}, respectively. Experimental mean grain yield was 5124 kg ha^{-1}. When combined over locations, experimental mean grain yield was 5673 kg ha^{-1}.

Table 1: CIMMYT code and pedigree of genotypes tested in multilocation trials during 2014/015

SN	Stock ID	Pedigree	Origin
1	ST43-2	CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-1-B	AF13A-ST702-3/ST702-2
2	ST43-32	CML451-B-B/CML323//(GEMS-0010 x CML479)-1-2-2-B	AF13A-ST702-57/ST702-56
3	HP1038-14	CLHP0003-B/CLHP0005-B//CLHP00322	CE13B-LT015-40/LT015-41
4	HP1038-10	CLHP0003-B/CLHP0005-B//CLHP0352	CE13B-LT015-28/LT015-29
5	HP1038-35	CLHP0003-B/CLHP0005-B//CLHP0452	CE13B-LT015-106/LT015-107
6	ST42-25	CML451-B-B/CML323//(AC-S 99MBRY-2)-B-20-3-1-B-B	AF13A-ST701-40/ST701-41
7	ST42-33	CML323/CML551//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B	AF13A-ST701-52/ST701-53
8	ST42-24	CML451-B-B/CLHP0002-B//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B	AF13A-ST701-39/ST701-38
9	ST42-8	CML486/CLHP0003-B//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	AF13A-ST701-13/ST701-14
10	ST42-27	CML451-B-B/CML323//(AC-S 99MBRY-1)-B-12-2-1-B-B	AF13A-ST701-43/ST701-44
11	ST42-9	CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	AF13A-ST701-15/ST701-14
12	ST42-17	CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	AF13A-ST701-28/ST701-29
13	ST42-30	CML551/CLHP0002-B//(P147-F2#152-S7/CML323)-F2-B-1-1-1	AF13A-ST701-48/ST701-47
14	ST42-16	CML496-B/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B	AF13A-ST701-27/ST701-26
15	ST42-6	CML486/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B	AF13A-ST701-10/ST701-11
16	ST43-33	CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-1-B	AF13A-ST702-60/ST702-59
17	ST43-43	CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-4-B	AF13A-ST702-81/ST702-80
18	ST43-41	CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-1-B	AF13A-ST702-78/ST702-77
19	ST43-26	CML451-B-B/CML323//(GEMS-0010 x CML373)-1-1-2-B	AF13A-ST702-48/ST702-47
20	ST43-6	CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-3-B	AF13A-ST702-12/ST702-11
21	ST43-24	CML486/CML327//(GEMS-0010 x CML373)-1-1-1-B	AF13A-ST702-43/ST702-44
22	ST43-21	CML451-B-B/CML323//[(Brazil Acc x Pop 45) x Pop 34-S0] x (BRAZ 1788/CML 327/Pop45 C8-S2)HS#19-1-1-2-1-1-B	AF13A-ST702-39/ST702-38
23	ST43-35	CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-2-B	AF13A-ST702-63/ST702-62
24	Local Check 1	RML-86 x RML-96	RML-86 x RML-96
25	Local Check 2	Poshilo Makai-1	S99TLWQ-HG-AB

Table 2. Geographical description of experimental locations

Location	Longitude	Latitude	Elevation (m) (m.a.s.l)
NMRP Rampur	84^{0}20'20.9"E	27^{0}39'0.3"N	228
ARS Surkhet	81^{0}47"E	28^{0}30"N	580
HRS Dailekh	81^{0}72"E	20^{0}85"N	1250-1355
Sandhikharka, Arghakhanchi	83^{0}14'48"E	28^{0}0'3"N	960

At HRS Dailekh, grain yield was in between 3524 (CLHP0003-B/CLHP0005-B//CLHP00322) and 8848 kg ha^{-1} (CML496-B/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B). Other high yielding genotypes were CML486/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B (8414 kg ha^{-1}), CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-3-B (7982 kg ha^{-1}), CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-4-B (7969 kg ha^{-1}) and CML451-B-B/CLHP0002-B//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B (7798 kg ha^{-1}).For grain yield, comparatively poor performance of the tested genotypes was observed at ARS Surkhet. Experimental mean grain yield was 3332 kg ha^{-1}. Grain yield ranged from 1237 (CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B) to 4668 kg ha^{-1} (CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-3-B).

Mean grain yield ranged from 4563 (CML451-B-B/CML323//[(Brazil Acc x Pop 45) x Pop 34-S0] x (BRAZ 1788/CML 327/Pop45 C8-S2)HS#19-1-1-2-1-1-B) to 7030 kg ha^{-1} (Local check RML-86 x RML-96). Genotypes identified promising were CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-3-B (6808 kg ha^{-1}), CML451-B-B/CLHP0002-B//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B (6382 kg ha-1), CML496-B/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B (6275 kg ha^{-1}), CML486/CLHP0003-B//(CML329/ CML20)F2-3-4-B-B-B-B-B (6201 kg ha^{-1}), CML551/ CLHP0002-B//(P147-F2#152-S7/CML323)-F2-B-1-1-1 (6111 kg ha^{-1}) and CLHP0003-B/CLHP0005-B//CLHP0352 (6095 kg ha^{-1}) (Table 3).

Table 3: Mean grain yield of pro-vitamin A maize genotypes at various locations, summer 2014/015

SN	Genotypes	Arghakhanchi	Dailekh	Surkhet	Rampur	Mean
24	Local Check1 RML-86 x RML-96	8872(4)	6852(11)	4124(5)	8273(1)	7030(1)
20	CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-3-B	7582(15)	7982(3)	4668(1)	7000(2)	6808(2)
8	CML451-B-B/CLHP0002-B//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B	8452(8)	7798(5)	3546(11)	5729(7)	6382(3)
14	CML496-B/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B	7654(14)	8848(1)	3087(18)	5510(9)	6275(4)
15	CML486/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B	6988(19)	8414(2)	3497(13)	5904(5)	6201(5)
13	CML551/CLHP0002-B//(P147-F2#152-S7/CML323)-F2-B-1-1-1	8600(7)	7385(7)	3150(17)	5309(12)	6111(6)
4	CLHP0003-B/CLHP0005-B//CLHP0352	7452(16)	7576(6)	3700(8)	5652(8)	6095(7)
10	CML451-B-B/CML323//(AC-S 99MBRY-1)-B-12-2-1-B-B	6871(20)	7384(8)	3480(14)	6578(4)	6078(8)
9	CML486/CLHP0003-B//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	8969(3)	5981(15)	4160(4)	5194(14)	6076(9)
5	CLHP0003-B/CLHP0005-B//CLHP0452	9108(1)	6199(14)	3902(6)	4980(15)	6047(10)
17	CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-4-B	8444(9)	7969(4)	4484(2)	3079(25)	5994(11)
19	CML451-B-B/CML323//(GEMS-0010 x CML373)-1-1-2-B	8407(10)	5561(18)	3509(12)	5844(6)	5830(12)
7	CML323/CML551//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B	7843(11)	6590(13)	2811(22)	5356(11)	5650(13)
16	CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-1-B	8775(6)	5840(16)	3874(7)	3568(23)	5514(14)
3	CLHP0003-B/CLHP0005-B//CLHP00322	9084(2)	3524(25)	3562(10)	5280(13)	5363(15)
1	CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-1-B	7768(12)	5554(19)	4376(3)	3682(22)	5345(16)
2	CML451-B-B/CML323//(GEMS-0010 x CML479)-1-2-2-B	7380(17)	6782(12)	3152(16)	3947(17)	5315(17)
18	CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-1-B	7234(18)	7228(9)	2958(19)	3734(21)	5289(18)
21	CML486/CML327//(GEMS-0010 x CML373)-1-1-1-B	7730(13)	5630(17)	1935(24)	5472(10)	5192(19)
11	CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	8818(5)	5040(23)	3222(15)	3567(24)	5162(20)
6	CML451-B-B/CML323//(AC-S 99MBRY-2)-B-20-3-1-B-B	6609(22)	5409(20)	2926(20)	4953(16)	4975(21)
12	CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	6640(21)	5222(21)	1237(25)	6695(3)	4948(22)
25	Local Check 2 Poshilo Makai-1	6036(24)	6879(10)	2182(23)	3850(20)	4737(23)
23	CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-2-B	5964(25)	4870(24)	3595(9)	3943(18)	4593(24)
22	CML451-B-B/CML323//[(Brazil Acc x Pop 45) x Pop 34-S0] x (BRAZ 1788/CML 327/Pop45 C8-S2)HS#19-1-1-2-1-1-B	6400(23)	5048(22)	2910(21)	3892(19)	4563(25)
Minimum		5964	3524	1237	3079	4563
Maximum		9108	8848	4668	8273	7030
Mean		7732	6442	3332	5124	5673
F-test						
Environment				**		
Genotype				**		
Genotype x Environment				*		
LSD (0.05)				499		
CV (%)				20		

Table 4. Mean days to 50% tasseling of pro-vitamin A maize genotypes at different locations, summer 2014/015

SN	Genotype	Arghakhanchi	Dailekh	Surkhet	Rampur	Mean
3	CLHP0003-B/CLHP0005-B//CLHP00322	67	53	51	49	55
5	CLHP0003-B/CLHP0005-B//CLHP0452	67	54	53	49	56
6	CML451-B-B/CML323//(AC-S 99MBRY-2)-B-20-3-1-B-B	70	55	50	50	56
9	CML486/CLHP0003-B//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	67	54	51	51	56
13	CML551/CLHP0002-B//(P147-F2#152-S7/CML323)-F2-B-1-1-1	67	55	52	49	56
10	CML451-B-B/CML323//(AC-S 99MBRY-1)-B-12-2-1-B-B	70	53	53	51	57
12	CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	71	56	51	51	57
19	CML451-B-B/CML323//(GEMS-0010 x CML373)-1-1-2-B	67	55	52	54	57
21	CML486/CML327//(GEMS-0010 x CML373)-1-1-1-B	68	55	54	53	57
1	CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-1-B	74	54	55	51	58
2	CML451-B-B/CML323//(GEMS-0010 x CML479)-1-2-2-B	70	56	53	53	58
4	CLHP0003-B/CLHP0005-B//CLHP0352	75	56	52	50	58
11	CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	70	55	55	53	58
14	CML496-B/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B	71	54	55	52	58
20	CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-3-B	70	55	54	53	58
22	CML451-B-B/CML323//[(Brazil Acc x Pop 45) x Pop 34-S0] x (BRAZ 1788/CML 327/Pop45 C8-S2)HS#19-1-1-2-1-1-B	74	55	52	53	58
23	CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-2-B	68	55	55	52	58
15	CML486/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B	72	56	55	52	59
16	CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-1-B	68	56	56	56	59
18	CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-1-B	74	57	55	52	59
7	CML323/CML551//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B	73	58	55	55	60
8	CML451-B-B/CLHP0002-B//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B	74	56	56	57	60
25	Local Check 2 Poshilo Makai-1	74	57	56	54	60
17	CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-4-B	73	57	55	56	61
24	Local Check1 RML-86 x RML-96	72	60	56	57	61
Minimum		67	53	50	49	55
Maximum		75	60	56	57	61
Mean		71	56	54	53	58
F-test						
Environment				**		
Genotype				**		
Genotype x Environment				**		
LSD (0.05)				1.64		
CV (%)				2.90		

Days to 50% Tasseling

Days to 50% tasseling among the tested genotypes were found highly significant. Effect of environment as well as G x E interactions were also recorded highly significant indicating the location specific nature of the genotypes. Days to 50% tasseling reached earlier at NMRP Rampur (53 days) followed by ARS Surkhet (54 days), HRS Dailekh (56 days) and Arghakhanchi (71 days), respectively. In Arghakhanchi, days to 50% tasseling ranged from 67 (CML451-B-B/CML323//(GEMS-0010 x CML373)-1-1-2-B) to 75 (CLHP0003-B/CLHP0005-B//CLHP0352). Similarly, this trait was in between 53 (CLHP0003-B/CLHP0005-B//CLHP00322) and 60 (Local check RML-86 x RML-96); 50 (CML451-B-B/CML323//(AC-S 99MBRY-2)-B-20-3-1-B-B) and 56 (Local heck RML-86 x RML-96); and 49 (CLHP0003-B/CLHP0005-B//CLHP00322) and 57 (Local check RML-86 x RML-96) at HRS Dailekh, ARS Surkhet and NMRP Rampur, respectively. In the entire environment except in Arghakhanchi Local check RML-86 x RML-96 was found latest (Table 4).

B//CLHP0352) with average value of 73. Similarly, this trait was in between 55 (CML451-B-B/CML323//(AC-S 99MBRY-1)-B-12-2-1-B-B and CLHP0003-B/CLHP0005-B//CLHP00322) and 61 (CML323/CML551//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B and Local check RML-86 x RML-96); 54 (CML451-B-B/CML323//(AC-S 99MBRY-2)-B-20-3-1-B-B and CLHP0003-B/CLHP0005-B//CLHP00322) and 59 (Local checks RML-86 x RML-96 and Poshilo Makai-1, CML451-B-B/CLHP0002-B//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B, CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-1-B and CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-1-B).); and 53 (CLHP0003-B/CLHP0005-B//CLHP0352, CML551/CLHP0002-B//(P147-F2#152-S7/CML323)-F2-B-1-1-1 and CLHP0003- B/CLHP0005-B//CLHP00322) and 60 (Local checkRML-86 x RML-96 and CML451-B-B/CLHP0002-B//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B) at HRS Dailekh, ARS Surkhet and NMRP Rampur, respectively. As days to 50% anthesis, in the entire environment except in Arghakhanchi, Local check RML-86 x RML-96 was found latest for this trait, too (Table 5).

Table 5. Mean days to 50% silking of pro-vitamin A maize genotypes at various locations, summer 2014/015

SN	Genotype	Arghakhanchi	Dailekh	Surkhet	Rampur	Mean
13	CML551/CLHP0002-B//(P147-F2#152-S7/CML323)-F2-B-1-1-1	70	57	55	53	56
3	CLHP0003-B/CLHP0005-B//CLHP00322	69	55	54	53	58
9	CML486/CLHP0003-B//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	69	56	55	55	58
5	CLHP0003-B/CLHP0005-B//CLHP0452	70	56	56	55	59
6	CML451-B-B/CML323//(AC-S 99MBRY-2)-B-20-3-1-B-B	73	57	54	55	59
10	CML451-B-B/CML323//(AC-S 99MBRY-1)-B-12-2-1-B-B	73	55	55	55	60
12	CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	73	58	55	55	60
14	CML496-B/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B	73	56	57	55	60
19	CML451-B-B/CML323//(GEMS-0010 x CML373)-1-1-2-B	70	57	55	58	60
21	CML486/CML327//(GEMS-0010 x CML373)-1-1-1-B	71	56	56	56	60
23	CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-2-B	71	58	56	56	60
1	CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-1-B	76	56	59	54	61
2	CML451-B-B/CML323//(GEMS-0010 x CML479)-1-2-2-B	73	58	56	57	61
4	CLHP0003-B/CLHP0005-B//CLHP0352	78	58	56	53	61
11	CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	72	57	58	56	61
15	CML486/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B	74	57	57	55	61
20	CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-3-B	73	58	56	57	61
22	CML451-B-B/CML323//[(Brazil Acc x Pop 45) x Pop 34-S0] x (BRAZ 1788/CML 327/Pop45 C8-S2)HS#19-1-1-2-1-1-B	76	57	55	57	61
16	CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-1-B	71	58	59	59	62
18	CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-1-B	77	57	57	55	62
7	CML323/CML551//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B	76	61	58	57	63
8	CML451-B-B/CLHP0002-B//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B	77	58	59	60	63
17	CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-4-B	76	59	57	59	63
25	Local Check 2 Poshilo Makai-1	76	59	59	57	63
24	Local Check1 RML-86 x RML-96	75	61	59	60	64
Minimum		69	55	54	53	56
Maximum		78	61	59	60	64
Mean		73	57	56	56	61
F-test						
Environment				**		
Genotype				**		
Genotype x Environment				ns		
LSD (0.05)				2.06		
CV (%)				3.40		

Days to 50% Silking

Days to 50% silking among the tested genotypes and effect of environment were recorded highly significant where as G x E interactions were found non-significant statistically showing the similar nature of the genotypes at various tested locations. Days to 50% silking reached earlier at NMRP Rampur (53 days) followed by ARS Surkhet (54 days) HRS Dailekh (55 days) and Arghakhanchi (69 days), respectively. In Arghakhanchi, days to 50% silking ranged from 69 (CML486/CLHP0003-B//(CML22 6/D888/ CML226/ CATETO) F2-B-1-1-B-B) to 78 (CLHP0003-B/CLHP0005-

Anthesis to Silking Interval

Anthesis to silking interval of the tested genotypes varied from location to location. In Arghakhanchi, this trait ranged from 2 to 3. Nine and 16 genotypes had ASI 2 and 3, respectively. At HRS Dailekh, genotype CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-1-B had the same day to 50% tasseling and silking. Three and 21 genotypes had 2 and 3 ASI, respectively. At ARS Surkhet, four groups of genotypes having ASI from 1 to 4 were recorded.

Only one genotype CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-2-B had ASI value 1. At NMRP Rampur, ASI ranged from 1 to 6. Among the tested genotypes, 1, 12, 10, 1 and 1 had ASI value 1, 2, 3, 4, 5 and 6, respectively (Table 6).

Plant Height

Highly significant differences among the tested genotypes as well as environmental effects were recorded for plant height.

Table 6. Anthesis to silking interval of pro-vitamin A maize genotypes at various locations, summer 2014/015

SN	Genotype	Arghakhanchi	Dailekh	Surkhet	Rampur	Mean
1	CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-1-B	2(1)	2(3)	4(4)	3(2)	3(3)
2	CML451-B-B/CML323//(GEMS-0010 x CML479)-1-2-2-B	3(2)	2(3)	3(3)	4(3)	3(3)
3	CLHP0003-B/CLHP0005-B//CLHP00322	2(1)	2(3)	3(3)	4(3)	3(3)
4	CLHP0003-B/CLHP0005-B//CLHP0352	3(2)	2(3)	4(4)	3(2)	3(3)
5	CLHP0003-B/CLHP0005-B//CLHP0452	3(2)	2(3)	3(3)	6(5)	3(3)
6	CML451-B-B/CML323//(AC-S 99MBRY-2)-B-20-3-1-B-B	3(2)	2(3)	4(4)	5(4)	3(3)
7	CML323/CML551//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B	3(2)	3(3)	3(3)	2(1)	3(3)
8	CML451-B-B/CLHP0002-B//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B	3(2)	2(3)	3(3)	3(2)	3(3)
9	CML486/CLHP0003-B//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	2(1)	2(3)	4(4)	4(3)	2(2)
10	CML451-B-B/CML323//(AC-S 99MBRY-1)-B-12-2-1-B-B	3(2)	2(3)	2(2)	4(3)	3(3)
11	CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	2(1)	2(3)	3(3)	3(2)	3(3)
12	CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	2(1)	2(3)	4(4)	4(3)	3(3)
13	CML551/CLHP0002-B//(P147-F2#152-S7/CML323)-F2-B-1-1-1	3(2)	2(3)	3(3)	4(3)	0(1)
14	CML496-B/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B	2(1)	2(3)	2(2)	3(2)	2(2)
15	CML486/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B	2(1)	1(2)	2(2)	3(2)	2(2)
16	CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-1-B	3(2)	2(3)	3(3)	3(2)	3(3)
17	CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-4-B	3(2)	2(3)	2(2)	3(2)	2(2)
18	CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-1-B	3(2)	0(1)	2(2)	3(2)	3(3)
19	CML451-B-B/CML323//(GEMS-0010 x CML373)-1-1-2-B	3(2)	2(3)	3(3)	4(3)	3(3)
20	CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-3-B	3(2)	3(3)	2(2)	4(3)	3(3)
21	CML486/CML327//(GEMS-0010 x CML373)-1-1-1-B	3(2)	1(2)	2(2)	3(2)	3(3)
22	CML451-B-B/CML323//[(Brazil Acc x Pop 45) x Pop 34-S0] x (BRAZ1788/CML 327/Pop45 C8-S2)HS#19-1-1-2-1-1-B	2(1)	2(3)	3(3)	4(3)	3(3)
23	CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-2-B	3(2)	3(3)	1(1)	4(3)	2(2)
24	Local Check1 RML-86 x RML-96	3(2)	1(2)	3(3)	3(2)	3(3)
25	Local Check 2 Poshilo Makai-1	2(1)	2(3)	3(3)	3(2)	3(3)

Table 7. Average plant height (cm) of pro-vitamin A maize genotypes at various locations, summer 2014/015

SN	Genotype	Arghakhanchi	Dailekh	Surkhet	Rampur	Mean
20	CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-3-B	205	207	188	200	200
6	CML451-B-B/CML323//(AC-S 99MBRY-2)-B-20-3-1-B-B	193	192	222	200	201
23	CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-2-B	198	184	225	205	203
19	CML451-B-B/CML323//(GEMS-0010 x CML373)-1-1-2-B	195	207	198	220	205
16	CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-1-B	210	206	197	220	208
21	CML486/CML327//(GEMS-0010 x CML373)-1-1-1-B	208	231	179	220	209
12	CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	190	221	208	220	210
10	CML451-B-B/CML323//(AC-S 99MBRY-1)-B-12-2-1-B-B	210	205	217	210	211
9	CML486/CLHP0003-B//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	208	224	190	235	214
22	CML451-B-B/CML323//[(Brazil Acc x Pop 45) x Pop 34-S0] x (BRAZ 1788/CML 327/Pop45 C8-S2)HS#19-1-1-2-1-1-B	213	211	211	220	214
11	CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	198	203	215	245	215
1	CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-1-B	210	224	232	220	222
5	CLHP0003-B/CLHP0005-B//CLHP0452	223	218	221	225	222
18	CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-1-B	218	232	205	240	223
14	CML496-B/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B	235	229	221	220	226
15	CML486/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B	220	237	214	235	226
13	CML551/CLHP0002-B//(P147-F2#152-S7/CML323)-F2-B-1-1-1	223	245	215	235	229
3	CLHP0003-B/CLHP0005-B//CLHP00322	230	226	219	245	230
17	CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-4-B	225	239	218	240	231
4	CLHP0003-B/CLHP0005-B//CLHP0352	218	232	234	245	232
7	CML323/CML551//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B	215	241	225	250	233
24	Local Check1 RML-86 x RML-96	265	232	204	245	236
8	CML451-B-B/CLHP0002-B//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B	260	233	216	240	237
25	Local Check 2 Poshilo Makai-1	220	245	230	255	237
2	CML451-B-B/CML323//(GEMS-0010 x CML479)-1-2-2-B	245	253	235	240	243
Minimum		190	184	179	200	200
Maximum		265	253	235	255	243
Mean		218	223	213	229	221
F-test						
Environment				**		
Genotype				**		
Genotype x Environment				ns		
LSD (0.05)				20.93		
CV (%)				9.60		

Table 8. Mean ear height (cm) of pro-vitamin A maize genotypes at various locations, summer 2014/015

SN	Genotype	Arghakhanchi	Dailekh	Surkhet	Rampur	Mean
23	CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-2-B	83	83	86	110	90
10	CML451-B-B/CML323//(AC-S 99MBRY-1)-B-12-2-1-B-B	95	89	72	125	95
6	CML451-B-B/CML323//(AC-S 99MBRY-2)-B-20-3-1-B-B	105	92	89	115	100
5	CLHP0003-B/CLHP0005-B//CLHP0452	103	104	88	110	101
19	CML451-B-B/CML323//(GEMS-0010 x CML373)-1-1-2-B	95	93	89	125	101
20	CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-3-B	98	102	95	110	101
1	CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-1-B	95	95	92	125	102
12	CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	85	105	94	125	102
16	CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-1-B	103	84	78	160	106
22	CML451-B-B/CML323//[(Brazil Acc x Pop 45) x Pop 34-S0] x (BRAZ 1788/CML 327/Pop45 C8-S2)HS#19-1-1-2-1-1-B	105	103	80	138	106
2	CML451-B-B/CML323//(GEMS-0010 x CML479)-1-2-2-B	115	112	87	120	109
17	CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-4-B	90	113	97	135	109
11	CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	95	106	88	150	110
3	CLHP0003-B/CLHP0005-B//CLHP00322	113	110	85	135	111
9	CML486/CLHP0003-B//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	105	105	101	135	111
18	CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-1-B	115	105	91	133	111
4	CLHP0003-B/CLHP0005-B//CLHP0352	110	95	105	140	112
21	CML486/CML327//(GEMS-0010 x CML373)-1-1-1-B	130	105	96	120	113
14	CML496-B/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B	123	109	85	140	114
8	CML451-B-B/CLHP0002-B//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B	113	112	96	150	118
25	Local Check 2 Poshilo Makai-1	118	112	103	140	118
15	CML486/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B	125	114	90	145	119
7	CML323/CML551//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B	118	122	99	145	121
24	Local Check1 RML-86 x RML-96	130	117	105	150	125
13	CML551/CLHP0002-B//(P147-F2#152-S7/CML323)-F2-B-1-1-1	110	116	97	185	127
Minimum		83	83	72	110	90
Maximum		130	122	105	185	127
Mean		107	104	91	136	109
F-test						
Environment				**		
Genotype				*		
Genotype x Environment				ns		
LSD (0.05)				15.10		
CV (%)				13.90		

Table 9. Plant height to ear height ratio of pro-vitamin A maize genotypes at various locations, summer 2014/015

SN	Genotype	Arghakhanchi	Dailekh	Surkhet	Rampur	Mean
1	CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-1-B	2.21(1)	2.36(1)	2.52(1)	1.76(2)	2.18(1)
2	CML451-B-B/CML323//(GEMS-0010 x CML479)-1-2-2-B	2.13(1)	2.26(1)	2.70(1)	2.00(1)	2.23(1)
3	CLHP0003-B/CLHP0005-B//CLHP00322	2.04(1)	2.05(1)	2.58(1)	1.81(2)	2.07(1)
4	CLHP0003-B/CLHP0005-B//CLHP0352	1.98(2)	2.44(1)	2.23(1)	1.75(2)	2.07(1)
5	CLHP0003-B/CLHP0005-B//CLHP0452	2.17(1)	2.09(1)	2.51(1)	2.05(1)	2.20(1)
6	CML451-B-B/CML323//(AC-S 99MBRY-2)-B-20-3-1-B-B	1.84(2)	2.08(1)	2.49(1)	1.74(2)	2.01(1)
7	CML323/CML551//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B	1.82(2)	1.98(2)	2.27(1)	1.72(2)	1.93(2)
8	CML451-B-B/CLHP0002-B//(Cel FSR/SPMAT/MBR 9958)-B-32-2-2-B-B	2.30(1)	2.00(1)	2.25(1)	1.60(2)	2.01(1)
9	CML486/CLHP0003-B//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	1.98(2)	2.13(1)	1.88(2)	1.74(2)	1.93(2)
10	CML451-B-B/CML323//(AC-S 99MBRY-1)-B-12-2-1-B-B	2.21(1)	2.30(1)	3.01(1)	1.68(2)	2.22(1)
11	CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	2.08(1)	1.92(2)	2.44(1)	1.63(2)	1.95(2)
12	CML486/CML327//(CML226/D888/CML226/CATETO)F2-B-1-1-B-B	2.24(1)	2.10(1)	2.21(1)	1.76(2)	2.06(1)
13	CML551/CLHP0002-B//(P147-F2#152-S7/CML323)-F2-B-1-1-1	2.03(1)	2.11(1)	2.22(1)	1.27(2)	1.80(2)
14	CML496-B/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B	1.91(2)	2.10(1)	2.60(1)	1.57(2)	1.98(2)
15	CML486/CLHP0003-B//(CML329/CML20)F2-3-4-B-B-B-B-B	1.76(2)	2.08(1)	2.38(1)	1.62(2)	1.90(2)
16	CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-1-B	2.04(1)	2.45(1)	2.53(1)	1.38(2)	1.96(2)
17	CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-4-B	2.59(1)	2.12(1)	2.25(1)	1.78(2)	2.12(1)
18	CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-1-B	1.90(2)	2.21(1)	2.25(1)	1.80(2)	2.01(1)
19	CML451-B-B/CML323//(GEMS-0010 x CML373)-1-1-2-B	2.05(1)	2.23(1)	2.22(1)	1.76(2)	2.03(1)
20	CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-3-B	2.09(1)	2.03(1)	1.98(2)	1.82(2)	1.98(2)
21	CML486/CML327//(GEMS-0010 x CML373)-1-1-1-B	1.60(2)	2.2(1)	1.86(2)	1.83(2)	1.85(2)
22	CML451-B-B/CML323//[(Brazil Acc x Pop 45) x Pop 34-S0] x (BRAZ1788/CML 327/Pop45 C8-S2)HS#19-1-1-2-1-1-B	2.03(1)	2.05(1)	2.64(1)	1.59(2)	2.02(1)
23	CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-2-B	2.39(1)	2.22(1)	2.62(1)	1.86(2)	2.26(1)
24	Local Check1 RML-86 x RML-96	2.04(1)	1.98(2)	1.94(2)	1.63(2)	1.89(2)
25	Local Check 2 Poshilo Makai-1	1.86(2)	2.19(1)	2.23(1)	1.82(2)	2.01(1)

However, G x E interactions were absent indicating similar nature of the trait at various locations. The tallest plant height of 229 cm was recorded at NMRP Rampur and the shortest at ARS Surkhet (213 cm). In Arghakhanchi, plant height ranged from 190 (CML486/CML327// (CML226/D888/CML226/CATETO)F2-B-1-1-B-B) to 265 cm (Local Check RML-86 x RML-96) with average value of 218. Similarly, this trait was in between 184 (CML451-B-B/CML323//(G EMS-0018 x CML311)-1-1-2-B) and 253 (CML451-B-B/CML323//(GEMS-0010 x CML479)-1-2-2-B); 179 (CML486/CML327//(GEMS-0010 x CML373)-1-1-1-B) and 235 (CML451-B-B/CML323//(GEMS-0010 x CML479)-1-2-2-B), and 200 (CML451-B-B/CML323//(GEM-0043 x CML465)-1-1-3-B and CML451-B-B/CML323//(AC-S

99MBRY-2)-B-20-3-1-B-B); and 255 (Local check Poshilo Makai-1) at HRS Dailekh, ARS Surkhet and NMRP Rampur, respectively (Table 7).

Ear Height

Differences among the tested genotypes were recorded significant for ear height. Similarly, environment effect on this trait was also highly significant. However, G x E interactions were absent indicating similar nature of the trait at various locations. Average ear height was taller at NMRP Rampur (185 cm) and shorter (105 cm) at ARS Surkhet (Table 8).

Plant Height to Ear Height Ratio

Plant height to ear height ratio ranged from 1.60 (CML486/CML327//(GEMS-0010 x CML373)-1-1-1-B) to 2.59 (CML451-B-B/CML323//(CML479 x GEM-0063)-1-1-4-B), 1.92 (CML486/CML327//(CM L226/D888/CML226/ CATETO)F2-B-1-1-B-B) to 2.45 (CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-1-B), 1.86 (CML486 /CML327//(G EMS-0010 x CML373)-1-1-1-B) to 3.01 (CML451-B-B/CML323//(AC-S 99MBRY-1)-B-12-2-1-B-B) and 1.27 (CML551/CLHP0002-B//(P147-F2#152-S7/CML323)-F2-B-1-1-1) to 2.05 (5) at Arghakhanchi, HRS Dailekh, ARS Surkhet and NMRP Rampur, respectively. Mean combined over locations was in between 1.80 (CML551/CLHP0002-B//(P147-F2#152-S7/CML323)-F2-B-1-1-1) to 2.26 (CML451-B-B/CML323//(GEMS-0018 x CML311)-1-1-2-B). Results have been presented in Table 9.

DISCUSSION

Grain yield differences among the tested genotypes were recorded highly significant. Genotypic (G) performance across the locations was also evident. Significant variations were recorded for genotype by environment (G x E) interactions which shows the location specific nature of the tested genotypes. Genotypes performed differently at various locations and shows the importance of different varieties at various locations.

At Arghakhanchi, HRS Dailekh and Surkhet 3, 9 and 4 genotypes performed better than check single cross normal maize (RML-86 x RML-96). Similarly, 23, 9, 22 and 19 tested pro-vitamin A genotypes outyielded the check open-pollinated variety Poshilo Makai-2. Increased levels of pro-vitamin A along with higher grain yields are the positive aspects of these varieties. Zambia, Nigeria, Ghana have already released pro-vitamin A maize. NARS in Malawi, Zimbabwe, Ethiopia, Uganda, Democratic Republic of Congo, Rwanda Benin, Ghana, Liberia, Sierra Leone, Mali, and Nigeria are testing pro-vitamin A genotypes in various nurseries. Hybrids and OPVs with up to 15 ppm provitamin A content are in the development pipeline (Dhliwayo et al., 2014). Maize varieties that contain high levels of beta-carotene – the precursor of vitamin A – offers hope against the menace of vitamin A deficiency that leads to blindness and, in some cases, even death among vulnerable groups particularly children, pregnant women, and mothers. Beta-carotene is converted by the body into vitamin A when the maize is consumed, thereby boosting the immune system (CGIAR, 2012; CIMMYT, 2013; Lunduka and Ndhlela, 2017).Days to 50% tasseling and silking among the tested genotypes and effect of environment were recorded highly significant. G x E interactions were found highly significant for days to 50% tasseling where as non-significant for days to 50% silking. ASI which ranged from 0 to 3 when combined over locations is an important trait for increasing production and productivity. A single genotype CML551/CLHP0002-B//(P147-F2#152-S7/CML323)-F2-B-1-1-1 had ASI value 0. Five and 19 genotypes had ASI 2 and 3, respectively. ASI varied from location to location, therefore varieties having ASI value 3 or less than 3 should be selected. A short ASI is a real measure of drought tolerance in maize (Ngugi et al., 2013; 2013a). Plant and ear height variations and environmental effects on them were found significant providing varietal selection options for these traits. Similar results were reported by previous researchers, too (Daniel and Bajtay, 1975; Wu, 1988; El-Sherbieny et al., 1991). Plant and ear heights are important characters deciding plants' behavior to lodging and response to fertilizer, and finally related to its productivity. Appropriate plant height to ear height ratio is two or more than two. It indicates that ear is placed below the middle portion of the plant. On the other hand, when this ratio is less than two plants are prone to lodging as ear placement is above the middle portion of the plant. Gyenes-Hegiy and his colleagues (2002) reported that this ratio is a stable trait for a particulat variety. Number of genotypes having this value more than 2 were 16, 22, 21 and 2 at Arghakhanchi, HRS Dailekh, ARS Surkhet and NMRP Rampur, respectively. Combined results over the locations showed that 15 genotypes performed better for this trait. Plants and ear heights were measured at the same time. If ear height is too high the weight of the ear may bend the stalk or even break it. Too lower ear height is unfavourable for yield and makes harvesting difficult, it protects the stalk from excessive weight (Zsubori Z et al., 2018).

Conclusion

Location specific high yielding pro-vitamin A genotypes are identified. For improving food and nutritional security, available pro-vitamin A genotypes with higher yields must be given priority instead of using supplements and fortified foods.

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