



Identification of Alternatives to Landraces of Kale (*Brassica oleracea* Group Acephala) for Off-season Cultivation and Seed-to-seed Production in Kashmir Valley

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Authors' contributions

This work was carried out in collaboration among all authors. Authors GM, JIM and OCS prepared the rationale and design of the study; Authors GM analyzed and interpreted the data; Authors AS and RAS collected, compiled and analyzed the data; Author SF and AJ contributed in writing the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To characterize kale (*Brassica oleracea* group Acephala) germplasm well adapted for July to December cropping season in Kashmir valley for suitability for year round cultivation with respect to leaf yield (t/ha).

Study Design: Random Complete Block Design with two replications.

Place and duration of study: The study was done in Vegetable Experimental Field of ICAR-Central Institute of Temperate Horticulture, Srinagar, Jammu and Kashmir, India from 2017-18 to 2018-19.

Methodology: The germplasm comprising breeding lines and landraces as checks was sown and then transplanted at different times of the year to evaluate for leaf yield potential at edible maturity stage. The final yield for each genotype was calculated by summing up all pickings. Critical differences among genotypes for total leaf yield were calculated from ANOVA using OPSTAT online tool for one factor analysis.

Results: Considering the average performance of two years in terms of leaf yield in tone per

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hectare, NW-Saag-1 (24.77, 25.08 and 25.01), CITH-KC-16 (28.79, 26.74 and 11.20) and CITH-KC-18 (24.25, 24.14 and 11.91) were found to yield significantly better than local checks *Khanyari* (7.77, 8.47 and 21.31) and *GM Dari* (10.36, 15.98 and 9.65) when transplanted in May, June and July, respectively. Months of April, May, June, July and August were most conducive for normal nursery production followed by May to September transplanting to get economical yields. January sowing of selected genotypes in polyhouse along with added protection from polysheet resulted in vigorous and healthy seedlings. Their transplanting in the second fortnight of March resulted only in short vegetative phase of the crop followed by bolting and seed production. However, this approach came out as an opportunity to produce seed in 7 months (January to July) compared to 1 year normally taken in farmer adopted seed production method.

Conclusion: NW-Saag-1, CITH-KC-16 and CITH-KC-18 lines yielded significantly higher than local landrace kales for offseason cultivation and seed-to-seed technique of seed production is an economic and short method of kale seed production in Kashmir valley.

Keywords: *Brassica oleracea* gp. *acephala*; kale; offseason; seed production.

1. INTRODUCTION

Kale (*Brassica oleracea* group *Acephala*) is popularly referred to as the king or queen of leafy vegetables due to its nutritional and non-nutritional health promoting factors. It has large, flat, green or purplish green leaves with cream or purple venation eaten cooked or pickled. Lately, kale has been increasingly becoming popular round the world due to better awareness on its nutritive and health promoting qualities and is now being honored as 'Superfood' [1]. It has high vitamins C and K, folic acid, beta carotene, dietary fibre and polyphenolic contents, and excellent antioxidant and anticarcinogenic properties [2,3]. In India, it is extensively cultivated in Kashmir and to lesser extent in Jammu and Himachal Pradesh. In Kashmir, it is a traditional crop used in heritage dishes as well as a staple vegetable eaten routinely. Referred to as '*haaq*' in vernacular, over time, kale has developed into many landraces popular for their specific traits, for example, *Khanyari* and *Kawdari* for large number of pickings, deep crinkles and meatiness of leaves and better taste at warmer temperatures; *GM Dari* for its large leaves accumulating great taste during winters and high yield per picking; *Anchaari* for succulent petioles suitable for pickling and *Hanz haaq* for small leaves picked several times throughout the winter.

In Kashmir, kale is mostly a winter season crop with seeding done in July and transplanting in August followed by multiple harvests in traditional varieties/ landraces throughout the winter. To a much lesser extent, *Khanyari* and *Kawdari*

landraces are cultivated during summer also (March – June). However, summer kale suffers from high infestation of cabbage butterfly during May and June. This forces farmers and kitchen gardeners to resort to aggressive chemical control, which is undesirable. The growers make their own seed by *ex-situ* method of seed production that involves taking crop, overwintering the remaining plant (in knob/ swollen stem form) without or with few leaves, *ex-situ* planting of plants in January-February and eventual flowering and seed setting from March to June. This is not only lengthy but also a laborious and costly procedure. With the mandate of research on temperate vegetable crops, ICAR-Central Institute of Temperate Horticulture, Srinagar has collected, conserved and improved large germplasm of kale from Kashmir valley over several years. Some of these collections and selections thereof have shown promise for greater yield and quality over existing landraces and farmers' varieties. Since local growers now take interest in alternatives to existing cultivars and their offseason production for higher income from vegetable crops in general, these selections were tested at institute's farm with an objective to assess their suitability for offseason cultivation and easier seed production [4,5]. The off-season essentially includes the months beyond July to December during which kale is conventionally cultivated. The outcome of this research will contribute to our efforts in ensuring year long remuneration to the growers from this popular crop and a short duration and cost labor effective seed production method.

2. MATERIAL AND METHODS

Table 1. Germplasm assessed for cultivation at different times of the year

S. no.	Genotypes	S. no.	Genotypes
1.	NW-Saag-1	14.	CITH-KC-20
2.	NW-Saag-4	15.	CITH-KC-23-KT
3.	NW-Saag-21 (LR)	16.	CITH-KC-26
4.	NW-Saag-23	17.	CITH-KC-26 (R)
5.	NW-Saag-27	18.	CITH-KC-38
6.	NW-Saag-33	19.	CITH-KC-40
7.	NW-Saag-38	20.	CITH-KC-48
8.	NW-Saag-42	21.	CITH-KC-Sel-3
9.	CITH-KC-8	22.	CITH-KC-Sel-5
10.	CITH-KC-11	23.	HW-1
11.	CITH-KC-14	24.	<i>Khanyari</i> (C)
12.	CITH-KC-16	25.	<i>GM Dari</i> (C)
13.	CITH-KC-18	26.	Japanese Green (C)

2.1 Plant Material

The morphologically uniform and stable germplasm with competent yield potential conserved and improved at the institute for several decades was assessed for two consecutive years for its performance during different times of the year. It comprised 26 genotypes (Table 1).

2.2 Planting of Germplasm

The selected lines were sown and transplanted each month of the year to evaluate their suitability for different durations of cultivation. Randomized Complete Block Design was used with two replicates of each block to lay experiment. Standard package of practices recommended by state agricultural university was followed to grow the crop [6].

2.3 Observations, Data Collection and Analysis

Observations were made on leaf yield, being the economical trait, as soon as the leaves reached edible maturity. It was repeated as often as a particular genotype expressed edible leaf bearing. Calculation of leaf yield (ton/hectare) was done on plot yield basis per picking and final yield for each genotype was obtained by summing up all pickings. Analysis of variance to compare genotypes for leaf yield was done using online OP Stat software for each date of transplanting.

3. RESULTS AND DISCUSSION

3.1 Time of Sowing

Sowing of each genotype throughout the year yielded information on relationship between time of sowing and success in recovering seedlings suitable for transplanting. The proportion of seedlings suitable for transplanting increased steadily from sowings attempted from March to July. Beyond July, seedling emergence was considerably reduced. Emergence ceased completely from October onwards in both the years. Open field sowing in October to February months of both the years resulted in complete failure in obtaining transplantable seedlings. However, in the second year, sowing was attempted in January keeping in mind the probability to transplant the crop in March. Additional protection received from covering the nursery of *Khanyari*, *GM Dari*, Japanese Green, *Hanz Haaq* and Siberian kale with a polysheet (same as used to clad polyhouse) inside a polyhouse induced congenial environment to produce healthy and vigorous seedlings suitable for transplanting in open field during March when temperature rose enough to support normal plant growth.

3.2 Time of Transplanting

Transplanting of seedlings of all genotypes obtained from each month of sowing resulted in steady increase followed by reduction in total yield, as the year progressed. However, there were few individual differences among genotypes with respect to the month when the highest yield

was achieved. The monthly averages for critical weather parameters (mean temperature and mean humidity) are presented in table 2 for observe relationship of weather with germplasm's yield performance. The graphical

patterns originating from mean yields of whole germplasm and those from genotypes that most consistently performed better than others across different dates are presented in figures 1 and 2, respectively.

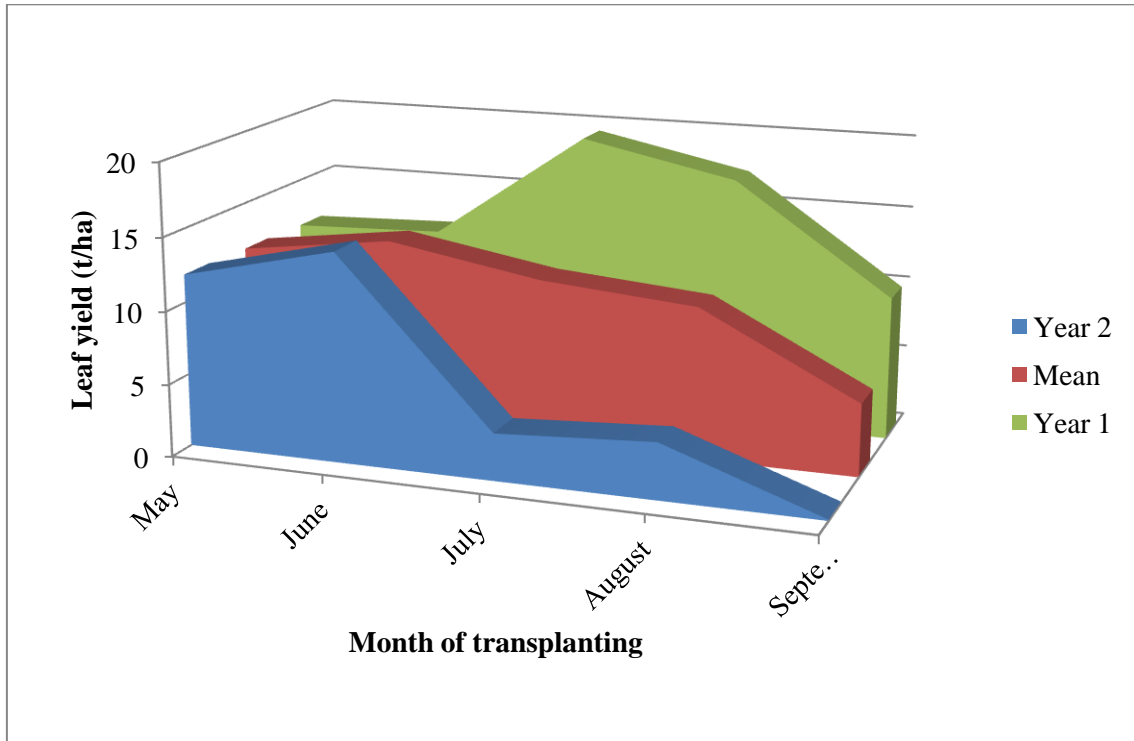
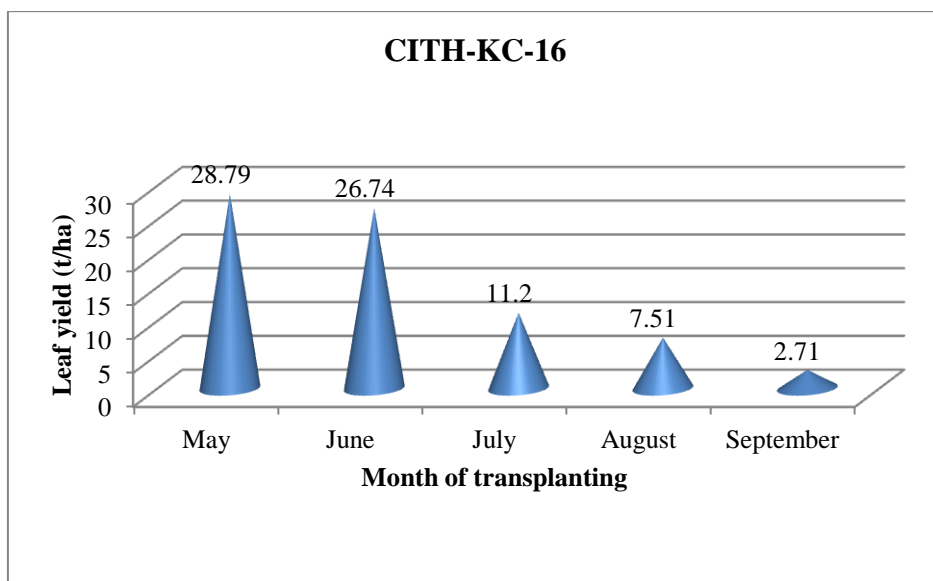


Fig. 1. Yearly and mean leaf yield (t/ha) of germplasm with respect to months of transplanting



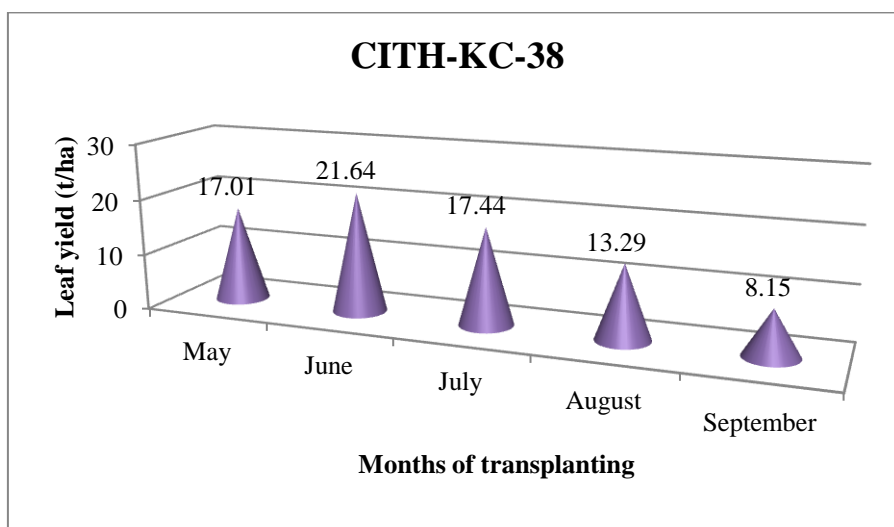
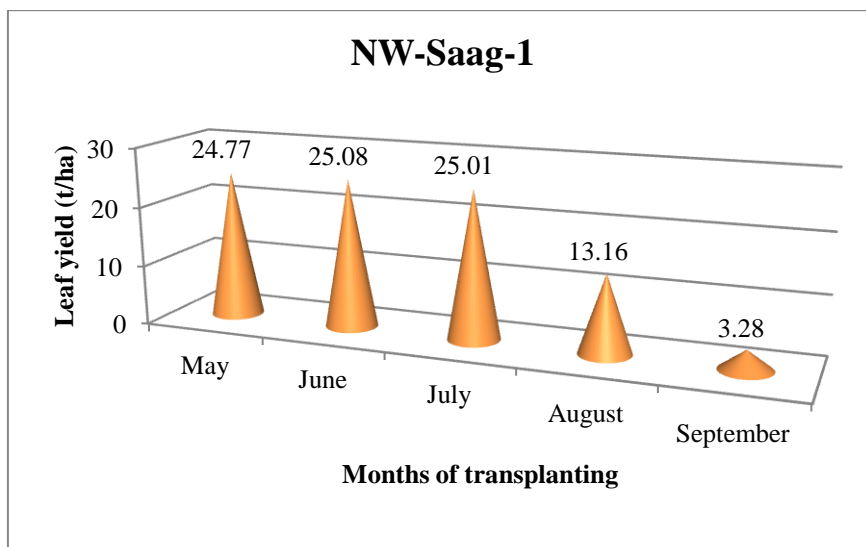
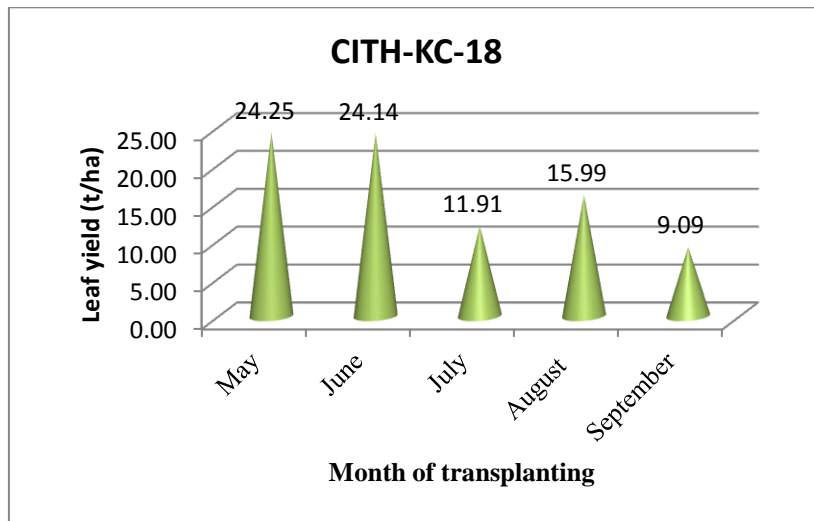
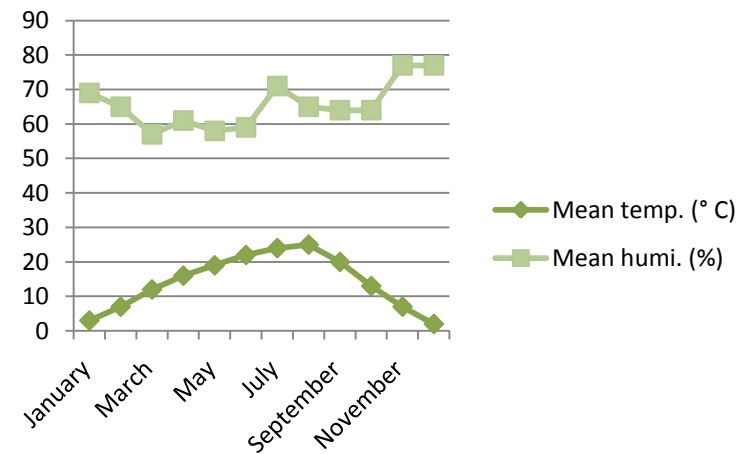
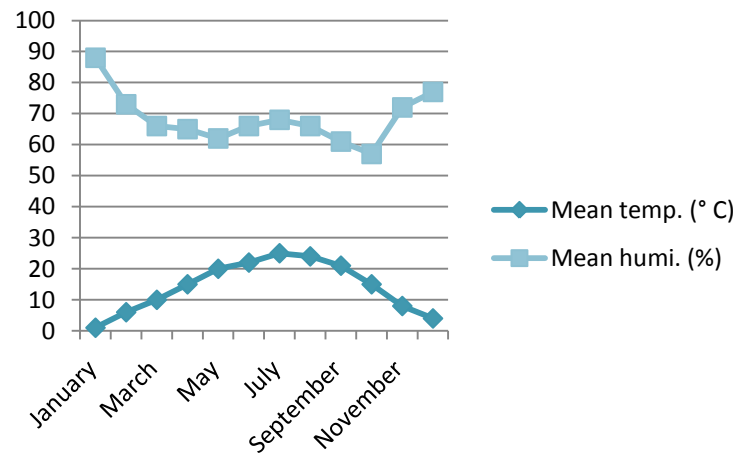


Fig. 2. Mean leaf yield (t/ha) of top performing genotypes over two years with respect to months of transplanting

Table 2. Monthly weather averages and their graphical presentation

Month	Year 1						Year 2					
	Temperature (°C)			Humidity (%)			Temperature (°C)			Humidity (%)		
	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean
January	15	-5	1	100	49	88	12	-5	3	97	26	69
February	15	-1	6	100	31	73	17	-2	7	97	18	65
March	25	1	10	100	21	66	27	3	12	100	12	57
April	37	1	15	100	20	65	28	6	16	100	15	61
May	30	9	20	96	26	62	30	10	19	95	18	58
June	33	13	22	94	23	66	34	14	22	97	14	59
July	32	16	25	93	32	68	32	14	24	93	31	71
August	33	13	24	100	31	66	33	16	25	98	31	65
September	29	11	21	100	24	61	30	9	20	94	29	64
October	28	5	15	92	22	57	26	3	13	100	20	64
November	22	-1	8	100	29	72	16	0	7	97	41	77
December	17	-3	4	97	29	77	12	-6	2	100	32	77



Source: www.timeanddate.com

Table 3. Leaf yield of kale genotypes at different times of transplanting

	Genotype	Year 1					Year 2				
		1 st FN	1 st FN	1 st FN	1 st FN	1 st FN	1 st FN	1 st FN	1 st FN	1 st FN	1 st FN
		May	June	July	August	Sept	May	June	July	August	Sept
1	NW-Saag-1	25.78	22.91	36.66	20.76	6.55	23.75	27.25	13.35	5.56	0
2	NW-Saag-4	15.85	19.46	25.43	19.97	11.25	17.75	22.43	1.32	3.65	0
3	NW-Saag-21 (LR)	16.25	11.97	17.63	11.98	8.56	16.97	14.31	9.86	2.69	0
4	NW-Saag-23	5.12	9.81	17.53	8.41	3.30	4.44	13.31	2.48	2.52	0.35
5	NW-Saag-27	2.41	3.08	13.01	14.38	5.62	0	3.09	0	0	0
6	NW-Saag-33	3.87	4.67	21.42	13.47	7.93	6.71	9.99	0.45	5.46	0
7	NW-Saag-38	7.33	5.91	20.46	21.58	10.05	8.85	7.94	0.55	9.39	0
8	NW-Saag-42	4.40	8.58	37.57	23.01	7.96	4.96	11.48	0.69	11.12	0
9	CITH-KC-8	5.47	7.95	9.13	4.74	2.15	9.17	10.73	1.91	1.33	0.32
10	CITH-KC-11	3.72	7.29	12.77	9.97	2.65	2.12	10.07	0	0.85	0
11	CITH-KC-14	8.66	9.65	13.37	2.87	1.46	8.98	12.95	1.81	1.71	0.40
12	CITH-KC-16	30.44	25.14	18.58	13.14	5.41	27.13	28.34	3.81	1.88	0
13	CITH-KC-18	25.48	23.89	20.98	29.52	18.18	23.02	24.39	2.83	2.45	0
14	CITH-KC-20	20.61	15.72	13.02	18.93	9.30	22.02	18.22	9.02	5.55	0
15	CITH-KC-23-KT	4.79	4.37	13.00	25.38	16.10	6.41	7.40	0.44	8.91	0
16	CITH-KC-26	4.12	7.14	6.00	10.94	5.06	4.67	6.97	2.52	2.04	0.26
17	CITH-KC-26 (R)	15.63	14.39	33.91	21.69	13.40	16.89	18.99	6.79	3.32	0
18	CITH-KC-38	17.27	20.62	27.85	23.82	16.29	16.75	22.66	7.89	2.75	0
19	CITH-KC-40	2.92	4.18	11.74	17.30	12.92	0	7.80	0	3.35	0
20	CITH-KC-48	11.30	9.96	14.09	8.94	4.03	11.15	9.70	1.11	1.88	0.33
21	CITH-KC-Sel-3	14.35	12.33	13.56	23.99	14.92	20.64	11.44	1.09	8.32	0
22	CITH-KC-Sel-5	10.40	11.73	18.24	7.56	8.72	10.64	14.87	1.22	1.69	0.26
23	HW-1	24.86	23.47	28.38	18.89	9.70	24.21	23.96	9.81	2.60	0
24	<i>Khanyari</i> (C)	8.25	8.05	41.90	30.75	9.51	7.29	8.88	0.71	4.29	0
25	<i>GM Dari</i> (C)	10.30	12.72	14.89	12.06	16.70	10.41	19.24	4.40	3.22	0.33
26	Japanese Green (C)	3.25	6.78	4.36	29.77	24.66	4.86	6.65	0	3.81	0
CD (P=.05)		5.09	4.73	11.17	11.11	6.31	7.09	6.09	4.00	4.41	-

Table 4. Leaf yield of kale genotypes and mean weather parameters at different transplanting times

	Genotype	Mean leaf yield over two years				
		May	June	July	August	September
1	NW-Saag-1	24.77	25.08	25.01	13.16	3.27
2	NW-Saag-4	16.79	20.94	13.38	11.81	5.62
3	NW-Saag-21 (LR)	16.61	13.14	13.74	7.33	4.28
4	NW-Saag-23	4.78	11.56	10.01	5.46	1.82
5	NW-Saag-27	1.20	3.08	6.51	7.19	2.81
6	NW-Saag-33	5.29	7.33	10.93	9.47	3.96
7	NW-Saag-38	8.09	6.93	10.50	15.48	5.03
8	NW-Saag-42	4.68	10.03	19.13	17.06	3.98
9	CITH-KC-8	7.32	9.34	5.52	3.03	1.24
10	CITH-KC-11	2.92	8.68	6.39	5.41	1.32
11	CITH-KC-14	8.82	11.30	7.59	2.29	0.93
12	CITH-KC-16	28.78	26.74	11.20	7.51	2.71
13	CITH-KC-18	24.25	24.14	11.90	15.98	9.09
14	CITH-KC-20	21.31	16.97	11.02	12.24	4.65
15	CITH-KC-23-KT	5.60	5.88	6.72	17.14	8.05
16	CITH-KC-26	4.39	7.05	4.26	6.49	2.66
17	CITH-KC-26 (R)	16.26	16.69	20.35	12.50	6.70
18	CITH-KC-38	17.01	21.64	17.87	13.28	8.15
19	CITH-KC-40	1.46	5.99	5.87	10.32	6.46
20	CITH-KC-48	11.22	9.83	7.60	5.41	2.18
21	CITH-KC-Sel-3	17.50	11.89	7.32	16.15	7.46
22	CITH-KC-Sel-5	10.52	13.30	9.73	4.63	4.49
23	HW-1	24.53	23.71	19.10	10.74	4.85
24	<i>Khanyari</i> (C)	7.77	8.46	21.30	17.52	4.75
25	<i>GM Dari</i> (C)	10.35	15.98	9.65	7.64	8.52
26	Japanese Green (C)	4.06	6.72	2.18	16.79	12.33
	CD (P=.05)	3.148	2.727	1.593	1.186	NS
	Average monthly temperature over 2 years	19.50	22.00	24.50	24.50	20.50
	Average monthly humidity over 2 years	60.00	62.50	69.50	65.50	62.50

Table 5. Leaf yield/ mean temperature/ mean humidity combinations obtained for kale germplasm during offseason cultivation

	1 st FN May	1 st FN June	1 st FN July	1 st FN August
Year 1	11.64/ 20/ 62	11.99/ 22/ 66	19.46/ 25/ 68	17.24/ 24/ 66
Year 2	11.91/ 22/ 66	14.35/ 22/ 59	3.23/ 24/ 71	3.86/ 25/ 65

3.3 Suitable Genotypes for Offseason Cultivation

There were significant differences among studied genotypes for yield performance tested at all transplanting times in the first as well as the second year (Table 3). The comparative mean

performances of each genotype and the germplasm on the whole over two years along with mean weather parameters is also shown in table 4 and 5, respectively..

Considering the first year, in May transplanting, which is about 3 months in advance to main

season transplanting (mid August) CITH-KC-16, CITH-KC-18 and NW-Saag-1 were the best yielders and performed statistically better than the best check *GM Dari* (10.30 t/ha). Furthermore, their yields (25.48 to 30.44 t/ha) were *at par* with recommended potential in local package of practices (Anonymous, 2017-18) despite offseason. Similarly, in June transplanting, CITH-KC-16, CITH-KC-18, HW-1, NW-Saag-1 and CITH-KC-38 (25.14 to 20.62) performed best and statistically superior to the best check *GM Dari* (12.72 t/ha). The yields realized were to the tune of main season yields. When transplanting was done in July, *Khanyari* expressed the highest leaf yield (41.90 t/ha). However, breeding lines NW-Saag-42, NW-Saag-1 and NW-Saag-21 LR (37.57 to 33.91 t/ha) performed at par with it. In August, *Khanyari* (30.75 t/ha) and Japanese Green (29.77 t/ha) check varieties yielded the highest but 9 breeding lines with yield potential ranging from 19.97 to 29.52 t/ha also performed at par with them.

The overall analysis of first year trial has shown that NW-Saag-1 made it to the category of most superior yielders at all the 4 dates of transplanting yielding 20.76 to 36.66 t/ha. Genotype CITH-KC-18 (20.98-29.52 t/ha) performed superior at three of the four dates of transplanting.

During the second year of study, there was unexpected heavy snow in the first week of November, which was much sooner than expected and affected the crop adversely. Had the weather been regular during second year of study, mean performance of whole germplasm as well as individual genotypes would have been higher. Nevertheless, yields were taken into consideration because it would not change the comparative performance of genotypes among themselves, even though absolute values of yield are lower than the genotypes' potential. Additionally, it gave an estimate of performance of these genotypes in the event of sudden temperature stress.

This crop continues to yield marketable leaves till December-January during winter cultivation except *Khanyari* that can yield beyond, although it is predominantly cultivated in summer season. Hence, the May transplanted crop well entered the month of November as much as the later transplanted crops. Therefore, the sudden stress did play a part in affecting yields at all transplanting dates. In May transplanting, CITH-

KC-16 yielded the highest leaf yield (27.13 t/ha) with 5 other genotypes HW-1 (24.21), NW-Saag-1 (23.75), CITH-KC-18 (23.02), CITH-KC-20 (22.02) and CITH-KC-Sel-3 (20.64) performing at par with it. This yield range coincides with the realized yields of kale in Kashmir (reference). This suggests buffering capacity of these genotypes to low temperature stress at later stages of cropping season. On the other hand, traditional varieties *Khanyari* (7.29), *GM Dari* (10.41) and Japanese Green (4.86), which were used as checks yielded sub-optimally under the same conditions. With respect to June transplanting, CITH-KC-16 (28.34) was again the best yielder with NW-Saag-1 (27.25), CITH-KC-18 (24.39) and HW-1 (23.96) again performing at par with it along with CITH-KC-38 (22.66) and NW-Saag-4 (22.43). The check varieties performed statistically inferior to the best genotype CITH-KC-16. In July and August transplanting, the yields obtained were comparatively very low despite being near main cropping season suggesting that sudden lowering of temperature and snow had greater impact on the earlier developmental stage of crop than at later stages (as in the case of May and June transplanting).

Considering the average performance of genotypes over two years, CITH-KC-16 (28.78 t/ha) alone outperformed all other genotypes including landraces and other checks when transplanted in May. In June transplanting, again CITH-KC-16 (26.74) along with NW-Saag-1 (24.77) and CITH-KC-18 (24.14) was the top performer. NW-Saag-1 (25.01) again performed best in July transplanting. With respect to transplanting in August, however, the highest average performance was exhibited by genotypes other than these three. Check Japanese Green (16.79), landrace *Khanyari* (17.52), CITH-KC-23 (17.14) and germplasm line NW-Saag-42 (17.06) were top performers. In September transplanting, however, no significant differences among genotypes were recorded, probably due to extremely skewed yields caused by temperature drop.

Also, it was observed that in August transplanting, which is also the main season of the crop, an introduced variety and a landrace were the top performers substantiating their claim over being the highest performing adapted genotypes. This implies that the germplasm held by CITH is very valuable in terms of the seasons other than the valley's main season along with other traits of importance.

3.4 Seed Production

The lifecycle of cultivated vegetable kale in the valley comprises embryo (seed) followed in succession by vegetative phase, vernalization, reproductive phase and then embryo (seed) again. In our attempt to cultivate our germplasm across all months, we were unable to achieve transplantable seedlings beyond August sowing in open field conditions. Although, sowing could be done in September till December in protected conditions, transplanting them in open fields during October to February period could not have been possible due to the obvious reason of inhospitable weather. However, sowing of certain genotypes was done in January in naturally ventilated polyhouse with second layer of poly-sheet over the nursery bed. Healthy seedlings were obtained, which were transplanted in mid March in open field. Luxuriant growth was achieved in all of them. However, with rise in temperature in May, bolting occurred, first in Japanese Green followed by others that eventually yielded viable seeds in July. This offseason production of seed is a great opportunity to circumvent vernalization phase that entails *ex-situ* field establishment and its care. This saves time and other resources and simplifies kale cultivation on the whole.

4. CONCLUSION

Kashmir is cultivating vegetable kale (*haaq/hakh*) since antiquity and hosts several landraces and farmers' varieties. However, with time, like all other crops, newer varieties in kale are also being demanded by farmers. Such varieties should have certain merits of relevance to the growers. Varieties with higher yields, better aesthetic quality, pest resistance and offseason production potential are of immense value to farmers. Kale, in this region, is primarily a winter crop sown in July, transplanted in August and harvested starting from September till December or until snowfall brings plant growth and development to a halt. There are a few exceptions like *Khanyari* and *Kawdari* that are sown in March-April and harvested during summer months, however, they require protection from pests (most importantly yellow cabbage butterfly and cabbage aphids) and diseases (mostly *Alternaria* leaf spot and downy mildew). A package of practices for offseason kale production can be an opportunity to exploit a better yielding genotype(s) at a time when there is no availability of kale in the market.

At ICAR-CITH, Srinagar, a large germplasm of kale is being maintained and improved for more than two decades. On evaluating this germplasm for offseason cultivation across many new dates of transplanting, genotype NW-Saag-1 followed by CITH-KC-18 and CITH-KC-16 were found to perform most consistently and better than others including landraces. Consequently, in this study, these genotypes have been identified as novel candidates for offseason kale cultivation (transplanting from May to July versus August transplanting in main season) that will yield earlier and higher than their conventional counterparts *Khanyari* and *GM Dari* popularly grown in Kashmir valley. It was observed that NW-Saag-1 yielded 17 % to 218 % higher than *Khanyari* and 57 % to 159 % higher than *GM Dari* when transplanted from May to July; CITH-KC-16 yielded 216 % to 271 % higher than *Khanyari* when transplanted in May-June and 16 % to 178 % higher than *GM Dari* when transplanted from May to July. Along the same trend CITH-KC-18 expressed 185 % to 212 % higher leaf yield than *Khanyari* on transplanting in May-June while 23 % to 134 % higher than *GM Dari* with respect to May to July transplanting. Further, polyhouse seedling preparation during harsh winters followed by mid March transplanting of some of these lines produced seed in seed-to-seed mode saving 5-month time and considerable efforts on growers' part.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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