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# BIPLOT ANALYSIS OF KASNI (*CICHORIUM INTYBUS* L.) COLLECTIONS

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## SUMMARY

In the present study biplot analysis was carried by using the 21 collections of kasni evaluated for 2016-17, 2017-18 and 2019-20. The results revealed increase in plant height for all the collections as observed from positive values of % change. Recent adaptability measures PRVG and HMPRVG settled for HCI-2, HCI-17, and HCI-3 as far as height of collections are concerned. Maximum change in number of branches had expressed by HCI-20, followed by HCI-19, HCI-17 while least increase exhibited by HCI-21, HCI-9. As per PRVG desirable collections would be HCI-4, HCI-11, and HCI-17 whereas HMPRVG measure settled for HCI-4, HCI-5, and HCI-6. Increase and decrease in seed yield per plot observed for the collections as only 05 collections had been maintained increase in seed yield per plot. Geometric Adaptability Index had expressed suitability of HCI-16, HCI-20, and HCI-19 whereas Harmonic mean measure found HCI-16, HCI-20, and HCI-19 as desirable ones. Biplot analysis observed 83.2% variation in plan height had been accounted by first two significant principal components with 58.6% and 24.6% of respective contributions. HCI-16, HCI-17, HCI-3, HCI-11 accounted by more values for first component whereas, contributions of HCI-7, HCI-20, HCI-6 as observed in second component. More than 91% of the total variation for branches per plant had been accounted by first two significant principal components with 59.3% and 31.7% of respective contributions. Mean, PRVG, GAI, HMPRVG were larger contributors for first while % change, coefficient of variation, 2017-18 & 2016-17 values for the second principal component. Nearly 92.4% of the total variation in seed yield per plot had been accounted by first two significant principal components with respective shares of 69.5% and 22.9%. Collections at vertex HCI-16, HCI-7, HCI-21, HCI-17, and HCI-20 in the biplots have the longest distance from the origin.

**Key words:** Kasni (*Cichorium intybus*), germplasm, bioplot analysis

Nearly 16.8% of total human beings and 20% of world's cattle and buffaloes survives on green plants and crop residues. The scarcity of feed as well as fodder has been well recognized at national level to obtain the anticipated production levels from livestock sector (Arya *et al*., 2022). Kasni (*Cichorium intybus*), perennial herb, plants show laxative, detoxifying, invigorating, blood-cleansing and anti-oxidative properties (Janda *et al.,* 2021). Chicory provides condensed tannins and other secondary metabolites, which positively affect the internal parasites in lambs, lowers the amount of methane production, and increase the reproductive rate in sheep (Perovi´c *et al.,* 2021). It is noted in a comparative study that faster growth rate is observed in lambs grazing on chicory than those grazing on other pastures also indicated that chicory and plantain mixture increased milk production in livestock (Nwafor et al., 2017; Peña-Espinoza et al., 2018). Cichorium intybus is grown and used in many parts of the world for various purposes as possess therapeutic and prophylactic quality, or for maintaining general wellbeing (Kirti and Arya, 2019). As a very versatile plant, it is beneficial to both animals and humans due to its high amounts of proteins, carbohydrates, minerals, and phyto bioactive elements (Kanj *et al.,* 2019; Arya *et al.,* 2020). In livestock production, it has been noted that some of its phyto constituents possess properties that improve the welfare of animals either in a parasitized state or otherwise. This makes chicory an ideal, cheap, natural, and sustainable livestock supplement or alternative feed material (Lombardi *et al.,* 2015). Further research on the multipurpose properties of the phyto bioactive elements found in chicory, their anti nutritional effects, effective dose of inclusion in animal diets, mechanism of action involved, and the biochemical description of the active PSM is strongly recommended (Ahmad *et al.,* 2020). Inulin found in chicory is a source of soluble dietary fiber, a prototype prebiotic especially beneficial in monogastric nutrition and also used as a functional food additive. The kasni flowers are utilized generally as a health tonic and appetite stimulant and also useful to treat gastroenteritis, cuts and bruises (Arya *et al.*, 2021).The seeds, flowers and roots of kasni are used medicinally to support liver health and treat liver-related problems. The establishment of this crop is comparatively slow as compared to other grasses. Once, this crop is established in grazing land it has a tremendous resistance to the repeated grazing as it has quick regeneration power. In India, green fodder is already insufficient. Therefore, the need is felt to feed dairy herds on medicinal plants to overcome the health issues (Arya *et al.,* 2020).

## MATERIALS AND METHODS

Twenty one collections of kasni (*Cichorium intybus*) were evaluated under field conditions during 2016-17, 2017-18 and 2018-19 in Herbal Garden of MAP Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar. The research centre is located at 29° 10' N latitude and 75° 46' E longitude with an elevation of 215.2m above the mean sea level. The soil of Hisar was found sandy loam (Typic Ustochrepts), tested medium in organic carbon (0.46%), available nitrogen (191kg/ha) and phosphorus (14kg/ha) and high in available potassium (340kg/ha). Each genotype was accommodated in two rows of four meter at spacing 30 x 10 cm in RBD in three replications. All the recommended package of practices was carried out to raise a good crop (Tyagi, 2008). Data were recorded on five randomly selected plants for height (m), number of branches, seed yield per plot and seed yield per hectare. The collected data were subjected to statistical analysis as per standard procedure using SAS 9.3 and JMP 9 software Three multivariate methods were used to analyze diversity, allowing sets of individuals to be described and grouped, while considering multiple characteristics and their interrelationships. Principal component analysis was used to quantify the contribution of the two components most associated with total variance, and to identify the variables characterizing each of these components. The hierarchical cluster analysis was used to group accessions according to diversity in morphological traits the genotype-by-traits (GT) biplot analysis to study the nature of association among the multiple traits and identification of promising genotypes which outperformed in certain traits (Verma *et al.*, 2021). Therefore, keeping the importance of this crop as animal fodder, present investigation on chicory was carried out.

## RESULTS AND DISCUSSION

### Divergence analysis

### Plant height

Changes in plant height among set of kasni collections tabulated vide Table 1. Increase in plant height observed for all the collections as observed from positive values of % change. Maximum change had observed for HCI-1 followed by HCI-13 while least observed for HCI-20 however the height decreased for HCI-17. Average height had expressed maximum value by HCI-16 followed by HCI-6, HCI-11 while least values maintained by HCI-17, HCI-3, HCI-2. Consistent plant height exhibited by HCI-7, HCI-17, HCI-8 as observed by least values of standard deviation (Fig. 1). Moreover, HCI-20, HCI-21, HCI-1 revealed the highest values of standard deviation. Collections HCI-7, HCI-6, HCI-8 achieved least values of Coefficient of Variation (CV) measure whereas HCI-20, HCI-1, HCI-21 expressed larger values. Geometric Adaptability Index (GAI) had expressed suitability of HCI-16, HCI-6, and HCI-11 whereas unsuitable ones were HCI-3, HCI-17, and HCI-2. Harmonic mean of Genotypic values (HMGV) measure found HCI-16, HCI-6, and HCI-5 as desirable collection besides that HCI-3, HCI-2, and HCI-17 would be of lower height among collections. HCI-2, HCI-17, HCI-3 selected by measure relative performance of genotypic values (RPGV) as suitable ones as far as height of collections

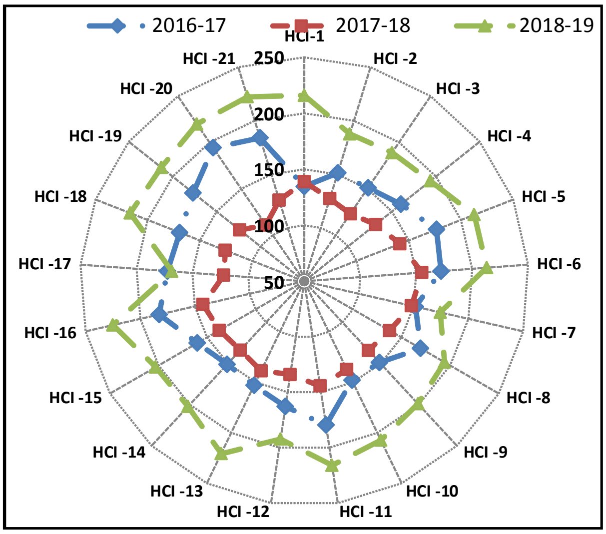

Fig. 1. Variation in Plant height for set of Kasni collections.

TABLE 1
Change in Plant Height of Kasni collections over years

| Genotype | 2016-17 | 2017-18 | 2018-19 | % change | Mean | Standard Deviation | CV | GAI | HM | PRVG | HMPRVG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HCI-1 | 134.70 | 139.00 | 216.00 | 60.36 | 163.23 | 45.75 | 28.03 | 159.32 | 155.86 | 0.971 | 0.958 |
| HCI-2 | 151.30 | 127.20 | 187.67 | 24.04 | 155.39 | 30.44 | 19.59 | 153.43 | 151.52 | 0.929 | 0.929 |
| HCI-3 | 151.00 | 123.00 | 189.00 | 25.17 | 154.33 | 33.13 | 21.46 | 151.98 | 149.67 | 0.921 | 0.921 |
| HCI-4 | 160.30 | 131.40 | 193.67 | 20.82 | 161.79 | 31.16 | 19.26 | 159.78 | 157.79 | 0.968 | 0.968 |
| HCI-5 | 176.70 | 141.60 | 212.67 | 20.36 | 176.99 | 35.54 | 20.08 | 174.58 | 172.18 | 1.058 | 1.057 |
| HCI-6 | 172.30 | 155.20 | 213.00 | 23.62 | 180.17 | 29.69 | 16.48 | 178.59 | 177.08 | 1.083 | 1.081 |
| HCI-7 | 151.70 | 148.00 | 174.33 | 14.92 | 158.01 | 14.25 | 9.02 | 157.59 | 157.19 | 0.960 | 0.949 |
| HCI-8 | 169.70 | 137.80 | 194.33 | 14.51 | 167.28 | 28.34 | 16.94 | 165.64 | 163.97 | 1.004 | 1.003 |
| HCI-9 | 148.70 | 134.00 | 199.00 | 33.83 | 160.57 | 34.09 | 21.23 | 158.28 | 156.15 | 0.960 | 0.958 |
| HCI-10 | 148.00 | 137.40 | 207.33 | 40.09 | 164.24 | 37.69 | 22.95 | 161.55 | 159.08 | 0.980 | 0.977 |
| HCI-11 | 179.70 | 144.40 | 216.00 | 20.20 | 180.03 | 35.80 | 19.89 | 177.63 | 175.24 | 1.076 | 1.076 |
| HCI-12 | 163.00 | 134.10 | 192.33 | 17.99 | 163.14 | 29.12 | 17.85 | 161.39 | 159.65 | 0.978 | 0.977 |
| HCI-13 | 153.00 | 138.60 | 220.67 | 44.23 | 170.76 | 43.82 | 25.66 | 167.26 | 164.09 | 1.015 | 1.011 |
| HCI-14 | 151.00 | 133.80 | 202.33 | 33.99 | 162.38 | 35.65 | 21.96 | 159.89 | 157.57 | 0.969 | 0.968 |
| HCI-15 | 160.00 | 137.40 | 203.00 | 26.88 | 166.80 | 33.32 | 19.98 | 164.64 | 162.57 | 0.998 | 0.997 |
| HCI-16 | 182.70 | 142.60 | 225.00 | 23.15 | 183.43 | 41.20 | 22.46 | 180.31 | 177.19 | 1.092 | 1.092 |
| HCI-17 | 172.30 | 122.00 | 168.33 | -2.30 | 154.21 | 27.97 | 18.13 | 152.38 | 150.44 | 0.928 | 0.919 |
| HCI-18 | 169.30 | 125.60 | 216.67 | 27.98 | 170.52 | 45.55 | 26.71 | 166.40 | 162.30 | 1.009 | 1.007 |
| HCI-19 | 176.70 | 123.60 | 213.00 | 20.54 | 171.10 | 44.96 | 26.28 | 166.93 | 162.65 | 1.013 | 1.009 |
| HCI-20 | 194.30 | 110.80 | 220.00 | 13.23 | 175.03 | 57.09 | 32.62 | 167.94 | 160.28 | 1.029 | 1.005 |
| HCI-21 | 184.00 | 125.80 | 222.33 | 20.83 | 177.38 | 48.60 | 27.40 | 172.65 | 167.77 | 1.049 | 1.043 |

are concerned along with HCI-6, HCI-11 & HCI-5 would be undesirable. Harmonic mean of relative performance of genotypic values HMRPVG measure settled for HCI-17, HCI-3, HCI-2 collections and unsuitable ones would be HCI-16, HCI-6, and HCI-5.

## Number of branches per plant

Positive increase in branches per plant had observed over the years for most of the kasni collections (Table 2). Maximum change had expressed by HCI-20, followed by HCI-19, HCI-17 while least increase exhibited by HCI-21, HCI-9 moreover decrease had also maintained by HCI-12, HCI-6, and HCI-8. Average number of branches per plant found maximum value of HCI-1, HCI-3, and HCI-7 collections whereas minimum of HCI-4, HCI-11, and HCI-4. Collections HCI-6, HCI-4, HCI-10 had retained the consistent performance over the years as evident by least values of standard deviation of the trait. HCI-1, HCI-19, HCI-3 would be of inconsistent performance. CV observed least values showed by HCI-6, HCI-4, HCI-10 and large values of HCI-19, HCI-1, and HCI-20. Large value of GAI had been maintained by HCI-8, HCI-7, and HCI-21 besides the least ones by HCI-4, HCI-11, and HCI-5. Measure HM observed maximum value by HCI-8, HCI 7, HCI 16 and least of HCI-4, HCI-5, and HCI-10 collections (Fig. 2). As per values of RPGV desirable collections would be HCI-4, HCI-11, HCI-17 whereas unsuitable would be HCI-8, HCI-7, HCI-21 as far as branches per plant is concerned. HMRPGV measure settled for HCI-4, HCI-5, and HCI-6 and also highlighted the HCI-7, HCI-8, and HCI-16 for their specific behaviour.

## Seed yield per plot

Changes in seed yield per plot among set of kasni collections tabulated vide Table 3. Increase and decrease seed yield per plot observed for the collections as observed from positive and negative values of % change. Out of 21, only five collections had been maintained increase in seed yield per plot. Maximum change had showed by HCI-7 followed by HCI-1, 5 while large decrease observed for 17, 21, HCI-18. Average seed yield per plot had expressed maximum value by HCI-16 followed by HCI-20, HCI-17 while least values maintained by HCI-7, HCI-6, HCI-9. Consistent values exhibited by HCI-2, HCI-6, HCI-7 as observed by least values of standard deviation. Moreover, large values of standard deviation showed by HCI-17, HCI-20, HCI-21. Collections HCI-2, HCI-4, HCI-11 achieved least values of CV measure whereas HCI-17, HCI-21, HCI-18 expressed larger values (Fig. 3). GAI had expressed suitability of HCI-16, HCI-20, and HCI-19 whereas unsuitable ones were

TABLE 2
Increase in number of Branches per plant over the years

| Genotype | 2016-17 | 2017-18 | 2018-19 | % change | Mean | Standard Deviation | CV | GAI | H M | PRVG | HMPRVG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HCI-1 | 6.70 | 5.40 | 24.00 | 258.21 | 12.03 | 10.38 | 86.32 | 9.54 | 7.98 | 1.214 | 1.100 |
| HCI-2 | 6.00 | 5.40 | 11.33 | 88.83 | 7.58 | 3.26 | 43.06 | 7.16 | 6.82 | 0.868 | 0.860 |
| HCI-3 | 10.00 | 4.20 | 21.00 | 110.00 | 11.73 | 8.53 | 72.75 | 9.59 | 7.78 | 1.210 | 1.103 |
| HCI-4 | 4.70 | 5.00 | 6.33 | 34.68 | 5.34 | 0.87 | 16.25 | 5.30 | 5.26 | 0.663 | 0.618 |
| HCI-5 | 3.30 | 7.00 | 8.00 | 142.42 | 6.10 | 2.48 | 40.59 | 5.70 | 5.25 | 0.765 | 0.626 |
| HCI-6 | 7.30 | 7.20 | 6.00 | -17.81 | 6.83 | 0.72 | 10.59 | 6.81 | 6.78 | 0.900 | 0.740 |
| HCI-7 | 8.30 | 7.20 | 19.33 | 132.89 | 11.61 | 6.71 | 57.78 | 10.49 | 9.64 | 1.276 | 1.257 |
| HCI-8 | 15.30 | 6.40 | 12.67 | -17.19 | 11.46 | 4.57 | 39.90 | 10.75 | 9.98 | 1.365 | 1.239 |
| HCI-9 | 10.00 | 5.40 | 12.33 | 23.30 | 9.24 | 3.53 | 38.16 | 8.73 | 8.19 | 1.066 | 1.043 |
| HCI-10 | 6.00 | 6.20 | 8.00 | 33.33 | 6.73 | 1.10 | 16.37 | 6.68 | 6.62 | 0.834 | 0.780 |
| HCI-11 | 4.00 | 4.80 | 9.00 | 125.00 | 5.93 | 2.69 | 45.29 | 5.57 | 5.27 | 0.687 | 0.658 |
| HCI-12 | 10.30 | 5.00 | 7.00 | -32.04 | 7.43 | 2.68 | 36.02 | 7.12 | 6.82 | 0.922 | 0.797 |
| HCI-13 | 7.00 | 6.40 | 11.33 | 61.86 | 8.24 | 2.69 | 32.64 | 7.98 | 7.74 | 0.972 | 0.954 |
| HCI-14 | 7.30 | 6.40 | 9.33 | 27.81 | 7.68 | 1.50 | 19.54 | 7.58 | 7.49 | 0.935 | 0.895 |
| HCI-15 | 8.70 | 6.20 | 13.67 | 57.13 | 9.52 | 3.80 | 39.94 | 9.03 | 8.59 | 1.092 | 1.089 |
| HCI-16 | 9.70 | 6.00 | 15.00 | 54.64 | 10.23 | 4.52 | 44.22 | 9.56 | 8.92 | 1.156 | 1.151 |
| HCI-17 | 5.00 | 4.00 | 14.00 | 180.00 | 7.67 | 5.51 | 71.81 | 6.54 | 5.75 | 0.807 | 0.774 |
| HCI-18 | 7.00 | 4.20 | 17.00 | 142.86 | 9.40 | 6.73 | 71.59 | 7.94 | 6.82 | 0.980 | 0.937 |
| HCI-19 | 6.30 | 3.60 | 21.33 | 238.57 | 10.41 | 9.55 | 91.77 | 7.85 | 6.21 | 1.021 | 0.887 |
| HCI-20 | 5.70 | 5.00 | 19.67 | 245.09 | 10.12 | 8.28 | 81.77 | 8.25 | 7.04 | 1.039 | 0.957 |
| HCI-21 | 13.00 | 4.80 | 14.67 | 12.85 | 10.82 | 5.28 | 48.82 | 9.71 | 8.49 | 1.218 | 1.130 |

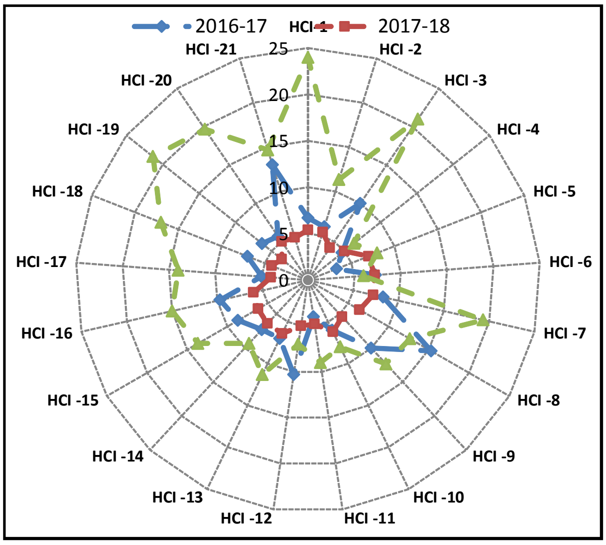


Fig. 2. Divergence in Number of branches for set of Kasni collections.

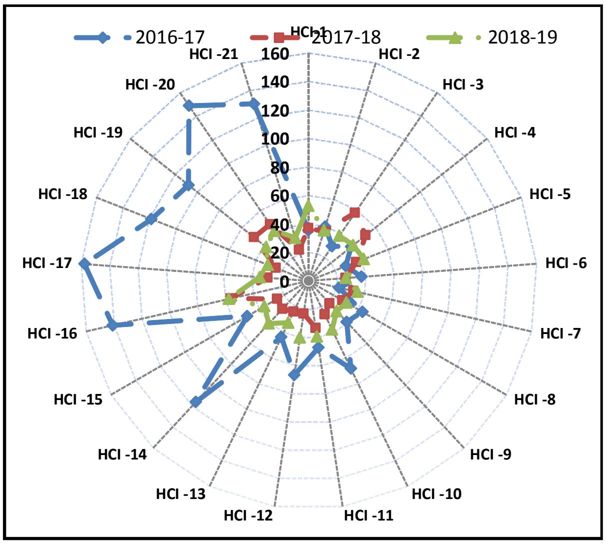


Fig. 3. Variation in seed yield per plot for set of Kasni collections.

HCI-9, HCI-7, and HCI-6. HMGV measure found HCI-16, HCI-20, and HCI-19 as desirable collection besides that HCI-9, HCI-7, and HCI-6 would be of lower seed yield per plot among collections. HCI-9, HCI-6, HCI-7 selected by measure RPGV as suitable ones as far as seed yield per plot of collections are concerned along with HCI-16, HCI-20 & HCI-17 would be undesirable. HMRPGV measure settled for HCI-7, HCI-9, HCI-6 collections and unsuitable ones would be HCI-16, HCI-20, and HCI-19.

## Seed yield per hectare

Change in seed yield per hectare had observed over the years for most of the kasni collections. Most of the collections had expressed decrease in seed yield per hectare over the years and only five were able to register an increase (Table 4). Maximum change had expressed by HCI-7, followed by HCI-5, HCI-3 while least increase exhibited by HCI-4 moreover maximum decrease had also maintained by HCI-17, HCI-21, and

TABLE 3
Change in Seed yield per plot for set of Kasni collections over years

| Genotype | 2016-17 | 2017-18 | 2018-19 | % change | Mean | Standard Deviation | CV | GAI | H M | PRVG | HMPRVG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HCI-1 | 35.39 | 36.93 | 52.69 | 48.88 | 41.67 | 9.57 | 22.98 | 40.99 | 40.37 | 0.991 | 0.818 |
| HCI-2 | 39.65 | 36.15 | 37.03 | -6.61 | 37.61 | 1.82 | 4.84 | 37.58 | 37.55 | 0.865 | 0.795 |
| HCI-3 | 29.40 | 57.69 | 38.33 | 30.37 | 41.81 | 14.46 | 34.59 | 40.21 | 38.74 | 1.040 | 0.746 |
| HCI-4 | 38.26 | 51.17 | 40.03 | 4.63 | 43.15 | 7.00 | 16.22 | 42.79 | 42.46 | 1.032 | 0.860 |
| HCI-5 | 28.10 | 36.03 | 41.67 | 48.29 | 35.27 | 6.82 | 19.33 | 34.81 | 34.35 | 0.851 | 0.681 |
| HCI-6 | 37.33 | 26.18 | 26.33 | -29.47 | 29.95 | 6.39 | 21.35 | 29.52 | 29.14 | 0.662 | 0.644 |
| HCI-7 | 22.00 | 32.27 | 35.17 | 59.86 | 29.81 | 6.92 | 23.21 | 29.23 | 28.61 | 0.729 | 0.556 |
| HCI-8 | 43.69 | 27.33 | 30.67 | -29.80 | 33.90 | 8.64 | 25.50 | 33.21 | 32.58 | 0.741 | 0.728 |
| HCI-9 | 39.42 | 21.66 | 29.00 | -26.43 | 30.03 | 8.92 | 29.72 | 29.15 | 28.30 | 0.651 | 0.639 |
| HCI-10 | 68.39 | 26.20 | 38.03 | -44.39 | 44.21 | 21.76 | 49.23 | 40.85 | 37.93 | 0.910 | 0.898 |
| HCI-11 | 47.40 | 33.51 | 39.67 | -16.31 | 40.19 | 6.96 | 17.32 | 39.79 | 39.40 | 0.899 | 0.861 |
| HCI-12 | 66.89 | 23.29 | 40.33 | -39.71 | 43.50 | 21.97 | 50.51 | 39.75 | 36.28 | 0.895 | 0.864 |
| HCI-13 | 43.95 | 24.13 | 32.67 | -25.67 | 33.58 | 9.94 | 29.61 | 32.60 | 31.64 | 0.729 | 0.714 |
| HCI-14 | 116.12 | 26.91 | 41.00 | -64.69 | 61.34 | 47.96 | 78.18 | 50.41 | 42.76 | 1.164 | 1.070 |
| HCI-15 | 49.60 | 25.42 | 35.67 | -28.08 | 36.90 | 12.14 | 32.89 | 35.56 | 34.27 | 0.794 | 0.780 |
| HCI-16 | 140.82 | 56.07 | 57.33 | -59.29 | 84.74 | 48.57 | 57.32 | 76.78 | 70.79 | 1.709 | 1.690 |
| HCI-17 | 157.51 | 28.74 | 34.33 | -78.20 | 73.53 | 72.79 | 98.99 | 53.76 | 42.69 | 1.316 | 1.095 |
| HCI-18 | 118.37 | 24.50 | 30.67 | -74.09 | 57.85 | 52.51 | 90.76 | 44.64 | 36.64 | 1.060 | 0.930 |
| HCI-19 | 107.64 | 48.93 | 38.00 | -64.70 | 64.86 | 37.45 | 57.74 | 58.49 | 53.53 | 1.315 | 1.273 |
| HCI-20 | 148.66 | 47.89 | 42.33 | -71.53 | 79.63 | 59.85 | 75.16 | 67.04 | 58.56 | 1.533 | 1.439 |
| HCI-21 | 129.88 | 22.7 | 31.67 | -75.62 | 61.42 | 59.46 | 96.81 | 45.37 | 36.00 | 1.105 | 0.925 |

HCI-18. Average seed yield per hectare found maximum value of HCI-7, HCI-20, and HCI-17 collections whereas minimum of HCI-7, HCI-6, and HCI-9. Collections HCI-2, HCI-6, HCI-5 had retained the consistent performance over the years as evident by least values of standard deviation of the trait. HCI-17, HCI-20, HCI-21 would be of inconsistent performance. CV observed least values showed by HCI-2, HCI-4, HCI-11 and large values of HCI-17, HCI-21, and HCI-18. Large value of GAI had been maintained by HCI-16, HCI-20, and HCI-19 besides the least ones by HCI-9, HCI-7, and HCI-6 (Fig. 4). Measure HMGV observed maximum value by HCI-16, HCI-19, HCI-20 and least of HCI-9, HCI-7, HCI-6 collections. As per values of RPGV desirable collections would be HCI-9, HCI-6, HCI-13 whereas unsuitable would be HCI-16, HCI-20, HCI-17 as far as branches per plant is concerned. HMRPGV measure settled for HCI-7, HCI-9, and HCI-6 and also highlighted the HCI-16, HCI-20, and HCI-19 for their specific behaviour.

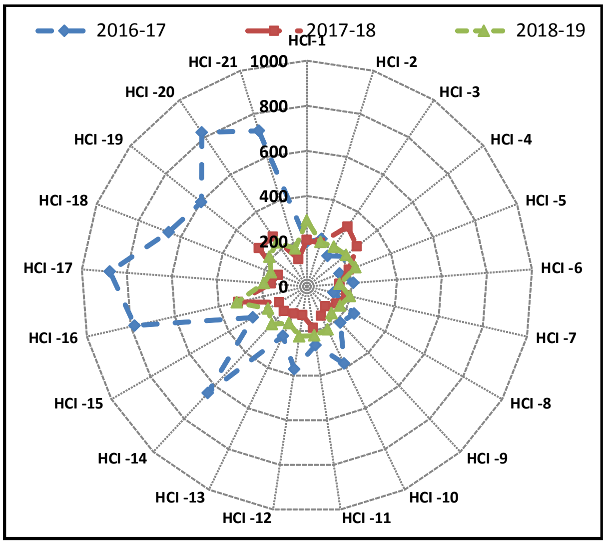

Fig. 4. Change in seed yield for set of Kasni collections.

## Biplot analysis

### Plant Height

Biplot compares the genotypes on the basis of multiple traits and interrelationship among the traits. Approximately 83.2% variation had been accounted by first two significant principal components with 58.6% and 24.6% of respective contributions (Table 5). Mean, RPGV, GAI, HMRPGV were larger contributors for first while number of standard deviation, coefficient of variation, 2017-18 mean value for the second one in biplot analysis. Performances of genotypes HCI-16, HCI-17, HCI-3, HCI-11 accounted by more values for first component whereas contributions of HCI-7, HCI-

TABLE 4
Change in Seed yield per hectare for set of Kasni collections over years

| Genotype | 2016-17 | 2017-18 | 2018-19 | % change | Mean | Standard Deviation | CV | GAI | HM | PRVG | HMPRVG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HCI-1 | 196.61 | 205.17 | 292.71 | 48.88 | 231.50 | 53.18 | 22.97 | 227.71 | 224.27 | 0.991 | 0.818 |
| HCI-2 | 220.28 | 200.84 | 205.72 | -6.61 | 208.95 | 10.11 | 4.84 | 208.79 | 208.63 | 0.865 | 0.795 |
| HCI-3 | 163.33 | 320.48 | 212.94 | 30.37 | 232.25 | 80.33 | 34.59 | 223.38 | 215.22 | 1.040 | 0.746 |
| HCI-4 | 212.56 | 284.29 | 222.38 | 4.62 | 239.74 | 38.89 | 16.22 | 237.75 | 235.87 | 1.033 | 0.861 |
| HCI-5 | 156.11 | 200.19 | 231.49 | 48.29 | 195.93 | 37.87 | 19.33 | 193.41 | 190.83 | 0.851 | 0.681 |
| HCI-6 | 207.39 | 145.44 | 146.27 | -29.47 | 166.37 | 35.53 | 21.36 | 164.01 | 161.86 | 0.662 | 0.644 |
| HCI-7 | 122.22 | 179.29 | 195.38 | 59.86 | 165.63 | 38.45 | 23.21 | 162.38 | 158.92 | 0.729 | 0.556 |
| HCI-8 | 242.72 | 151.85 | 170.38 | -29.80 | 188.32 | 48.02 | 25.50 | 184.49 | 181.00 | 0.741 | 0.728 |
| HCI-9 | 219.00 | 120.34 | 161.11 | -26.43 | 166.82 | 49.58 | 29.72 | 161.93 | 157.21 | 0.651 | 0.639 |
| HCI-10 | 379.94 | 145.53 | 211.27 | -44.39 | 245.58 | 120.91 | 49.24 | 226.90 | 210.72 | 0.910 | 0.898 |
| HCI-11 | 263.33 | 186.15 | 220.38 | -16.31 | 223.29 | 38.67 | 17.32 | 221.06 | 218.86 | 0.898 | 0.861 |
| HCI-12 | 371.61 | 129.36 | 224.05 | -39.71 | 241.67 | 122.08 | 50.52 | 220.84 | 201.55 | 0.895 | 0.864 |
| HCI-13 | 244.17 | 134.07 | 181.50 | -25.67 | 186.58 | 55.23 | 29.60 | 181.12 | 175.81 | 0.729 | 0.714 |
| HCI-14 | 645.11 | 149.51 | 227.77 | -64.69 | 340.80 | 266.43 | 78.18 | 280.07 | 237.55 | 1.164 | 1.070 |
| HCI-15 | 275.56 | 141.23 | 198.16 | -28.09 | 204.98 | 67.42 | 32.89 | 197.57 | 190.40 | 0.794 | 0.780 |
| HCI-16 | 782.33 | 311.49 | 318.49 | -59.29 | 470.77 | 269.84 | 57.32 | 426.56 | 393.27 | 1.709 | 1.690 |
| HCI-17 | 875.06 | 159.64 | 190.72 | -78.20 | 408.47 | 404.37 | 99.00 | 298.67 | 237.15 | 1.316 | 1.095 |
| HCI-18 | 657.61 | 136.09 | 170.38 | -74.09 | 321.36 | 291.71 | 90.77 | 247.97 | 203.56 | 1.060 | 0.930 |
| HCI-19 | 598.00 | 271.81 | 211.11 | -64.70 | 360.31 | 208.07 | 57.75 | 324.96 | 297.38 | 1.315 | 1.273 |
| HCI-20 | 825.89 | 266.07 | 235.16 | -71.53 | 442.37 | 332.49 | 75.16 | 372.47 | 325.32 | 1.533 | 1.439 |
| HCI-21 | 721.56 | 126.08 | 175.94 | -75.62 | 341.19 | 330.35 | 96.82 | 252.02 | 199.99 | 1.105 | 0.925 |

20, HCI-6 as observed in second component (Fig. 5).The vertex genotypes HCI-7, HCI-17, HCI-20, HCI-16, in the biplots have the longest distance from the origin of biplot as these may be best or poor in some or all of the traits (Fig. 3). GAI had expressed strong relationship with RPGV & HMRPGV while positive relationship maintained with HMGV as well as with Mean. Standard deviation and CV are positively related with % change in plant height of collections. Standard deviation had expressed right angle with 2017-18 plant height values and % change with HMGV measure. CV also showed 90 degree angle with HM measure. % change, CV with standard deviation and 2018-19 plant height values were placed

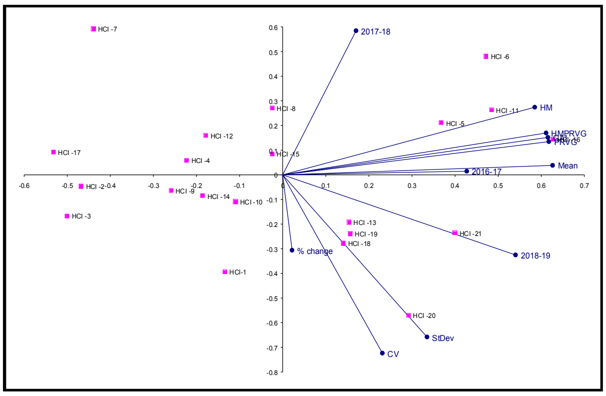


Fig. 5. Biplot analysis of measures of height and set of Kasni collections.

TABLE 5
Loadings of measures of height as per principal components

| Height | PC1 | PC2 | Height | PC1 | PC2 | Height | PC1 | PC2 |
|---|---|---|---|---|---|---|---|---|
| 2016-17 | 0.2681 | 0.0113 | HCI-1 | -0.0862 | -0.3105 | HCI -11 | 0.3086 | 0.2093 |
| 2017-18 | 0.1070 | 0.4559 | HCI -2 | -0.2988 | -0.0360 | HCI -12 | -0.1143 | 0.1269 |
| 2018-19 | 0.3391 | -0.2537 | HCI -3 | -0.3195 | -0.1314 | HCI -13 | 0.0975 | -0.1514 |
| % change | 0.0136 | -0.2387 | HCI -4 | -0.1426 | 0.0468 | HCI -14 | -0.1188 | -0.0664 |
| Mean | 0.3932 | 0.0296 | HCI -5 | 0.2342 | 0.1681 | HCI -15 | -0.0161 | 0.0676 |
| Standard Deviation | 0.2102 | -0.5131 | HCI -6 | 0.3004 | 0.3818 | HCI -16 | 0.3995 | 0.1156 |
| CV | 0.1451 | -0.5642 | HCI -7 | -0.2807 | 0.4700 | HCI -17 | -0.3398 | 0.0735 |
| GAI | 0.3864 | 0.1182 | HCI -8 | -0.0162 | 0.2157 | HCI -18 | 0.0895 | -0.2192 |
| HM | 0.3672 | 0.2138 | HCI -9 | -0.1657 | -0.0501 | HCI -19 | 0.0994 | -0.1883 |
| PRVG | 0.3877 | 0.1048 | HCI -10 | -0.0704 | -0.0858 | HCI -20 | 0.1856 | -0.4504 |
| HMPRVG | 0.3837 | 0.1323 | | | | HCI -21 | 0.2544 | -0.1859 |
| 83.16 | 58.58 | 24.58 | | | | | | |

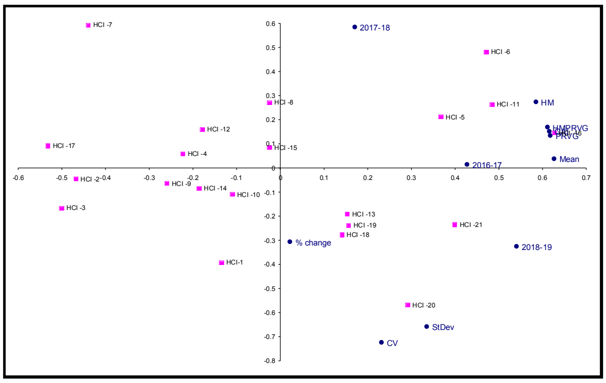

Fig. 6. Clustering pattern among measures of height for set of Kasni collections.

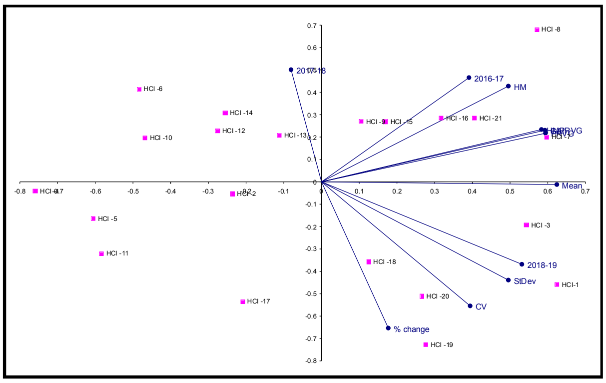

Fig. 7. Biplot analysis of measures of branches per plant and set of Kasni collections.

in second quadrant of biplot analysis while considering nearly 83% variations among the measures (Fig. 6). Values of 2016-17 observed in third quadrant with cluster of Mean with HMGV, RPGV, HMRPGV, GAI besides with values of plant height for 2017-18.

## Branches/plant

More than 91% of the total variation among measures and set of collections had been accounted by first two significant principal components with 59.3% and 31.7% of respective contributions (Table 6). Mean, RPGV, GAI, HMRPGV were larger contributors for first while % change, coefficient of variation, 2017-18 & 2016-17 values for the second principal component in biplot analysis. Performances of genotypes HCI-4, HCI-1, HCI-5, and HCI-7 accounted by more values for first component whereas contributions of HCI-19, HCI- 08, HCI-17, and HCI-20 as observed in second component (Fig. 7).The vertex genotypes HCI-8, HCI-6, HCI-7, HCI-17, and HCI-1 in the biplots have the longest distance from the origin of biplot. CV expressed direct relationship with % change, standard deviation and values of branches per plant for 2018-19. Mean values were also directly associated with% change. GAI had expressed very tight positive association with RPGV and HMRPGV and HMGV with values of branches for 2016-17. Ninety degree angle expressed by % change with HMGV, CV with values of 2016-17, mean with 2017-18 values. Straight line angle observed for % change with 2017-18 values. % change, CV with standard deviation, mean and 2018-19 number of branches values were placed in second quadrant of biplot analysis while considering nearly 91% variations among the measures. Values of 2016-17 observed in third quadrant with HMGV along with cluster of RPGV, HMRPGV, GAI measures (Fig. 8). The values of number of branches for 2017-18 observed as outlier and placed in last quadrant.

## Seed yield per plot

Nearly 92.4% of the total variation had been accounted by first two significant principal

TABLE 6

Loadings of measures of branches per plant as per principal components

| Branches | PC1 | PC2 | Branches | PC1 | PC2 | Branches | PC1 | PC2 |
|---|---|---|---|---|---|---|---|---|
| 2016-17 | 0.2448 | 0.3406 | HCI-1 | 0.3189 | -0.2738 | HCI -11 | -0.2987 | -0.1911 |
| 2017-18 | -0.0505 | 0.3665 | HCI -2 | -0.1211 | -0.0317 | HCI -12 | -0.1414 | 0.1372 |
| 2018-19 | 0.3326 | -0.2695 | HCI -3 | 0.2775 | -0.1147 | HCI -13 | -0.0573 | 0.1253 |
| % change | 0.1108 | -0.4782 | HCI -4 | -0.3884 | -0.0244 | HCI -14 | -0.1309 | 0.1850 |
| Mean | 0.3905 | -0.0090 | HCI -5 | -0.3098 | -0.0978 | HCI -15 | 0.0864 | 0.1615 |
| Standard Deviation | 0.3100 | -0.3211 | HCI -6 | -0.2477 | 0.2480 | HCI -16 | 0.1619 | 0.1705 |
| CV | 0.2467 | -0.4056 | HCI -7 | 0.3050 | 0.1201 | HCI -17 | -0.1073 | -0.3194 |
| GAI | 0.3710 | 0.1686 | HCI -8 | 0.2916 | 0.4070 | HCI -18 | 0.0634 | -0.2130 |
| H M | 0.3101 | 0.3127 | HCI -9 | 0.0536 | 0.1622 | HCI -19 | 0.1411 | -0.4345 |
| PRVG | 0.3717 | 0.1587 | HCI -10 | -0.2398 | 0.1182 | HCI -20 | 0.1356 | -0.3052 |
| HMPRVG | 0.3651 | 0.1708 | | | | HCI -21 | 0.2071 | 0.1706 |
| 91.03 | 59.30 | 31.73 | | | | | | |

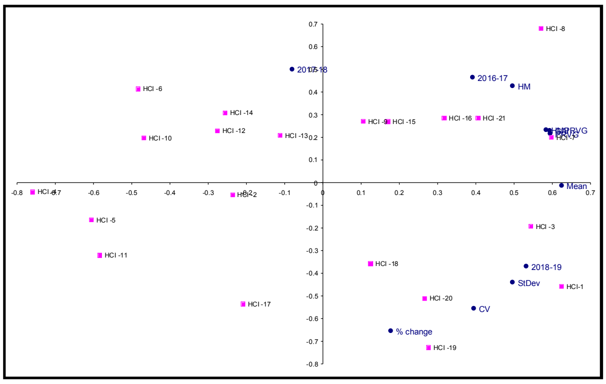


Fig. 8. Clustering pattern among measures for branches per plant.

components with 69.5% and 22.9% of respective contributions (Table 7). Measures Mean, GAI, RPGV, HMRPGV were more contributors for first while 2017-18 values, 2018-19 values, % change, coefficient of variation, for the second principal components in biplot analysis. Contributions of HCI-16, HCI-20, HCI-17, HCI-7 accounted by more for first component whereas contributions of HCI-16, HCI-21, HCI-18 as observed in second component (Fig. 9).The vertex genotypes HCI-16, HCI-7, HCI-21, HCI-17, HCI-20 in the biplot have the longest distance from the origin of biplot.

Values of 2018-19 tightly related with 2017-18 values and HMGV measure. CV showed right angle with 2018-19 values while Standard deviation with 2017-18 values of seed yield of the collections. HMGV also maintained 90 degree angle with % changes values. Similar nature of GAI and RPGV also observed with % change Straight line angle between CV and % change reflect the no relationship between two measures as far as seed yield of collections were concerned. Standard deviation values showed positive relation with CV and seed yield values for 2016-17. Measure CV expressed direct association with mean seed yield of collections. Very tight direct association of GAI with

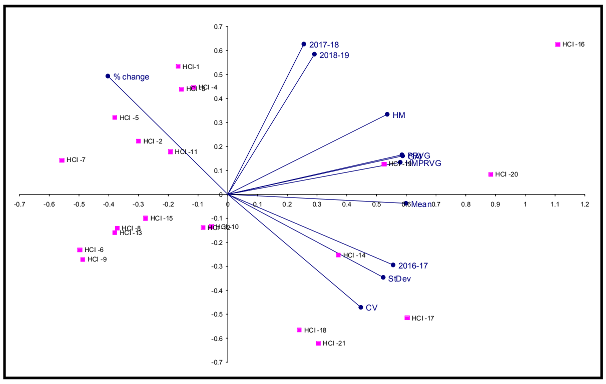


Fig. 9. Biplot analysis of measures of seed yield and set of Kasni collections.

RPGV and HMRPGV exhibited by studied measures and positively related with HMGV also. % change, CV with standard deviation and 2016-17 seed yield per plot plant height values were placed in second quadrant with mean values by biplot analysis while considering nearly 92.4% variations among the measures. Values of 2017-18 observed with 2018-19 in third quadrant with cluster of Mean with HMGV, RPGV, HMRPGV, GAI measures (Fig. 10). The values of seed yield per plot for % change had placed in fourth quadrants (Verma *et al.*, 2021).

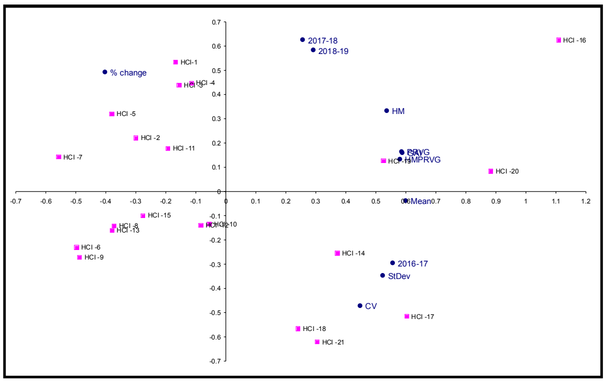


Fig. 10. Clustering pattern among measures for seed yield per plot.

TABLE 7

Loadings of measures of seed yield as per principal components

| Seed yield | PC1 | PC2 | Seed yield | PC1 | PC2 | Seed yield | PC1 | PC2 |
|---|---|---|---|---|---|---|---|---|
| 2016-17 | 0.3343 | -0.2338 | HCI-1 | -0.0799 | 0.3346 | HCI -11 | -0.0921 | 0.1120 |
| 2017-18 | 0.1538 | 0.4968 | HCI -2 | -0.1429 | 0.1390 | HCI -12 | -0.0399 | -0.0866 |
| 2018-19 | 0.1752 | 0.4635 | HCI -3 | -0.0743 | 0.2749 | HCI -13 | -0.1805 | -0.1001 |
| % change | -0.2423 | 0.3910 | HCI -4 | -0.0549 | 0.2804 | HCI -14 | 0.1759 | -0.1585 |
| Mean | 0.3601 | -0.0298 | HCI -5 | -0.1807 | 0.2010 | HCI -15 | -0.1314 | -0.0617 |
| Standard Deviation | 0.3143 | -0.2749 | HCI -6 | -0.2366 | -0.1440 | HCI -16 | 0.5258 | 0.3921 |
| CV | 0.2690 | -0.3741 | HCI -7 | -0.2650 | 0.0898 | HCI -17 | 0.2857 | -0.3223 |
| GAI | 0.3534 | 0.1271 | HCI -8 | -0.1768 | -0.0882 | HCI -18 | 0.1139 | -0.3538 |
| H M | 0.3225 | 0.2645 | HCI -9 | -0.2317 | -0.1693 | HCI -19 | 0.2490 | 0.0796 |
| PRVG | 0.3520 | 0.1307 | HCI -10 | -0.0266 | -0.0838 | HCI -20 | 0.4189 | 0.0532 |
| HMPRVG | 0.3487 | 0.1057 | | | | HCI -21 | 0.1441 | -0.3885 |
| 92.42 | 69.47 | 22.94 | | | | | | |

## CONCLUSIONS

The kasni genotype HCI-16 was tallest in plant height accompanied with more number of branches per plant; thus it was found best suited for fodder production. In addition to this, it was highest seed yielder also. Contributions of HCI-16 accounted by more for first component as well as in second component. The genotype HCI-16 had observed at vertex in the biplots and expressed the longest distance from the origin of biplot. Therefore, it is concluded that the kasni genotype HCI-16 may be best suited for establishment as grazing fodder crop in grass lands.

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