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Screening for yield-related agronomic traits in a panel of locally conserved common bean (*Phaseolus vulgaris* L.) accessions

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Characterization and conservation of germplasm is a critical step toward the genetic improvement of the crop. This study assessed variation in 257 common bean genotypes which included 207 accessions obtained the National Gene Bank of Kenya, 33 accessions from Kenya Agricultural and Livestock Research Organization (KALRO), 13 landraces collected from farmers' fields and four commercial varieties for various agronomic traits. The experiments were laid out in a randomized complete block design with three replicates at Jomo Kenyatta University of Agriculture and Technology (Kenya) for four seasons between 2019 and 2020. Significant differences (P≤0.05) existed among the common bean accessions for all traits studied. Seed yield ranged from 220.6 to 4641.9 kg/ha (KNB0106) among the accessions with a mean of 1267.0 kg/ha. Significant (P ≤0.05) positive correlation was recorded for days to flowering and days to maturity (0.73), while 100-seed weight had a significantly negative correlation with the number of pods per plant (-0.66) and the number of seeds per pod (-0.65). High (>20%) broad-sense heritability was recorded for 100-seed weight (89.0%), days to flowering (76.8%), and grain yield (60.5%). Nineteen accessions that combined early maturity and high-yielding traits were identified. On average, higher seed yields were recorded for large-seeded and climbing genotypes compared to small-seeded and bush types. Common bean accessions characterized can be exploited in breeding programs.

Key words: Common bean, agronomic traits, *Phaseolus vulgaris*, variability, broad sense heritability.

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is an important crop for human nutrition. It is a major source of protein, carbohydrates, dietary fiber, and essential minerals to a large population globally (Gepts et al., 2008). A wide diversity of traits exists in common bean with regard to growth habit, duration to maturity, resistance to biotic and abiotic stresses, seed size, seed color, and yield (Wortmann et al., 1998). These variations serve as

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genetic resources that have been extensively exploited in breeding programs to develop varieties (Pérez-Vega et al., 2010). Studies have shown that the common bean has two distinct centers of genetic differentiation, namely the Middle American and Andean gene pools (Bitocchi et al., 2012). The Andean bean types (large-seeded) are the most popular beans in Africa even though their yield has been reported to be lower compared to the middle American bean types (small-seeded) (Beebe, 2012).

Van Schoonhoven and Pastor-Corrales (1987) categorized growth habits into five groups ranging from determinate bush to indeterminate climbing. The bush types are preferred because they do not require support and are hence convenient for market production (Okii et al., 2014). Bush types are also popular for commercial production because they are early maturing and can be harvested mechanically thus require less labor. On the other hand, climbing common bean are popular in highland areas because they have higher yields and are ideal for small-scale farmers with a limited land size (Wortmann et al., 1998).

Preference for common bean grains varies among consumers depending on several parameters which include seed color and seed size. In eastern Africa, the Calima seed type (Red speckled or Rosecoco type) is the most popular followed by medium and small reds. Large reds including red kidney rank third in popularity, followed by navy, whites, purples, and black, respectively (Wortmann et al., 1998).

Heritability estimates of a trait indicate how much variation can be attributed to genetic variation and the environmental influence in the expression of the trait. The heritability estimates therefore aid a breeder to select a breeding procedure that will efficiently improve the performance of the genes involved (Yohannes et al., 2020).

Improving seed yield is a primary objective for most common bean breeding programs (Vandemark et al., 2014). Seed yield is a polygenic trait that is conditioned by three yield components, the number of pods per plant, the number of seeds per pod, and seed weight (Adams, 1967; Kamfwa et al., 2015). The knowledge of the association between these seed yield attributes may help in the selection of a suitable donor to improve this trait. The objective of this study was to assess common bean accessions for variation in yield related agronomic traits which are essential for characterization, conservation, and breeding.

MATERIALS AND METHODS

Field experimental site

Field experiments were carried out for four seasons at Jomo Kenyatta University of Agriculture and Technology (JKUAT) in Kiambu County Kenya. The site is located at coordinates 3^o 35'South and 36^o 35' East at an elevation of 1520 m above sea level. The site experiences bimodal pattern of rainfall with an annual mean of 856 mm. Long rains occur between March and May while short rains occur between October and November with a monthly mean of 142 and 116 mm, respectively. The mean annual maximum and minimum temperatures are 20 and 30°C, respectively. The area falls under ecological zone four with three types of soils namely deep clay soils (vertisols).

Plant materials

A total of 257 common bean accessions were used in this study, accessions from the National Gene Bank of Kenya, 33 from Regional Agricultural Research Centre-Kenya Agricultural and Livestock Research Organization (KALRO)-Embu, 13 landraces collected from farmers' fields and four commercial varieties (GLP-2; GLP-24, GLPx92 and GLP1192a). The growth habits of the genotypes were type I & II, III and IV with 124, 84 and 49 accessions, respectively. The genotypes belonged to different market classes found in the region (Table 1).

Experimental design and trial management

The experiment was conducted for four seasons during the long and short raining seasons of 2019 and 2020. The trial was laid out as a randomized complete block design with three replicates. At planting, the genotypes were separated into climbing and non-climber types to avoid shading of bush types. The bean lines were grown in single rows of 5 m in length. The bush genotypes were planted with an inter-row spacing of 40 cm while the climbing genotypes had an inter-row spacing of 50 cm, the intra-row spacing of all the genotypes was 20 cm. Compound N.P.K (17.17.17) fertilizer was applied at a rate of 200 kg/ha, evenly spread, and thoroughly mixed with soil. The bean seeds were planted and lightly covered with soil. The first manual weed control was conducted two weeks after emergence and the second one at 40 to 50 days thereafter. Insect pests and diseases were controlled by the application of chemical pesticides diazinon at a rate of 40 ml/20 L and 500 g/L pymetrozine at a rate of 400 to 600 g/ha. Before flowering, the climbing genotypes were supported with 1.5 m long sticks to prevent lodging.

Agronomic data collection

Data collection started one month after planting. The quantitative traits studied are described in Table 2.

Statistical analysis

Analysis of variance

Qualitative data collected was used to group the accessions into their growth habits and market classes. Quantitative data collected from field experiments were combined over seasons and analyzed using R software (version 4.0.2). All traits' means were separated using Fisher's Least Significance Difference test (LSD) at 5% level. The significance of correlations was tested at 0.05 and 0.01 levels of probability. Cluster analyses were carried out based on Euclidean distance method. Complete clustering method was used to determine the genetic relationship among genotypes based on the agronomic data.

Phenotypic and genotypic coefficient of variation

The estimates of phenotypic and genotypic coefficient of variation

Table 1. Market classes of common bean accessions used in this study.

Seed class	Description	Number of accessions
Pintos	Cream with brown specks-GLPx92 type	22
Sugars	Cream and can be speckled	39
Calima	Rosecoco type	25
Small reds	Red haricot type	15
Large reds	Canadian wonder type	17
Purples	Mwezimoja type	11
Medium whites	Medium and large whites	13
Brown and tan	Brown and orange	19
Cariocas	Red and Red specks	28
Yellow	Yellow coloured	8
Blacks	Black coloured	23
Navy	Small whites	37
Total	-	257

Source: Author's work.

Table 2. Quantitative agronomic traits recorded in field trials.

Trait	Units	Description
Phenological traits		
Days to flowering	Days	No. of days from planting to the date when 50% of plants have one or more flowers
Days to maturity	Days	No. of days after planting to the date when 50% of the plants reached physiological maturity
Yield and yield components		
Number of pods	no.	The average total number of pods from five randomly selected plants per plot at maturity
Pod length	cm	Average pod length of five randomly selected pods from each plot measured using a ruler
Number of seed per pod	no.	The average number of seeds of five randomly selected pods from each plot
Seed weight	g	Weight of a random sample of 100 seeds from each plot
Grain yield	g	Total seed yield per plot which will be used to extrapolate yield per hectare

Source: Author's work.

were calculated as described by Singh and Chaudhary (1985) as follows:

$$PCV\ (\%) = \frac{\sqrt{\text{Vp}}}{\text{Mean}} X100, \qquad GCV\ (\%) = \frac{\sqrt{\text{Vg}}}{\text{Mean}} X100$$

where PCV is the phenotypic coefficient of variance, Vp is the phenotypic variance, GCV is genotypic coefficient of variance, and Vg is the genotypic variance, GCV and PCV values were categorized as low (0-10%), moderate (10-20%) and high (20% and above) as indicated by Burton and de Vane (1953).

Heritability

Heritability was estimated as the ratio of genotypic variance to phenotypic variance as described by Singh and Chaudhary (1985).

$$H^2 = \frac{Vg}{Vp} X100$$

where H^2 is broad-sense heritability, Vp is phenotypic variance and Vg is genotypic variance. Heritability percentage values were categorized as low (0-30%), moderate (30-60%), and high (60% and above) as described by Johnson et al. (1955).

RESULTS

Descriptive statistics for agronomic and seed yield traits

The means, range, variance, and coefficient of variation for recorded traits are summarized in Table 3. The coefficient of variation ranged from 4.2% (days to flowering) to 36.1% (number of pods per plant). The highest coefficient of variation registered was for the number of pods per plant and grain yield at 36.1 and 32.3%, respectively. Cluster analysis based on the agronomic traits grouped the 257 genotypes into two major groups. The largest group constituted 82.1% of the

Table 3. Descriptive statistics for agronomic traits, seed yield, and yield components for 257 common bean accessions grown at Juja in 2018 and 2019.

Trait	Mean	Range	Min	Max	Variance	SE	CV%
Days to flowering	37.8	12.6	32.5	45.1	16.4	0.8	4.2
Days to maturity	82.0	17.5	73.9	91.4	33.1	1.9	4.6
Pods/Plant (No.)	12.6	24.0	5.9	29.9	56.6	2.6	36.1
Pod length (cm)	9.9	7.8	6.9	14.7	4.4	0.7	14.6
Seed/Pod (No.)	4.6	3.7	3.0	6.7	1.1	0.4	17.3
100-Seed weight (g)	36.9	54.9	15.0	69.9	183.7	2.3	15.5
Yield (kg/ha)	1267.0	4421.3	220.6	4641.9	678470.6	204.8	32.3

n=257, SE= Standard error, CV= Coefficient of variation.
Source: Author's work.

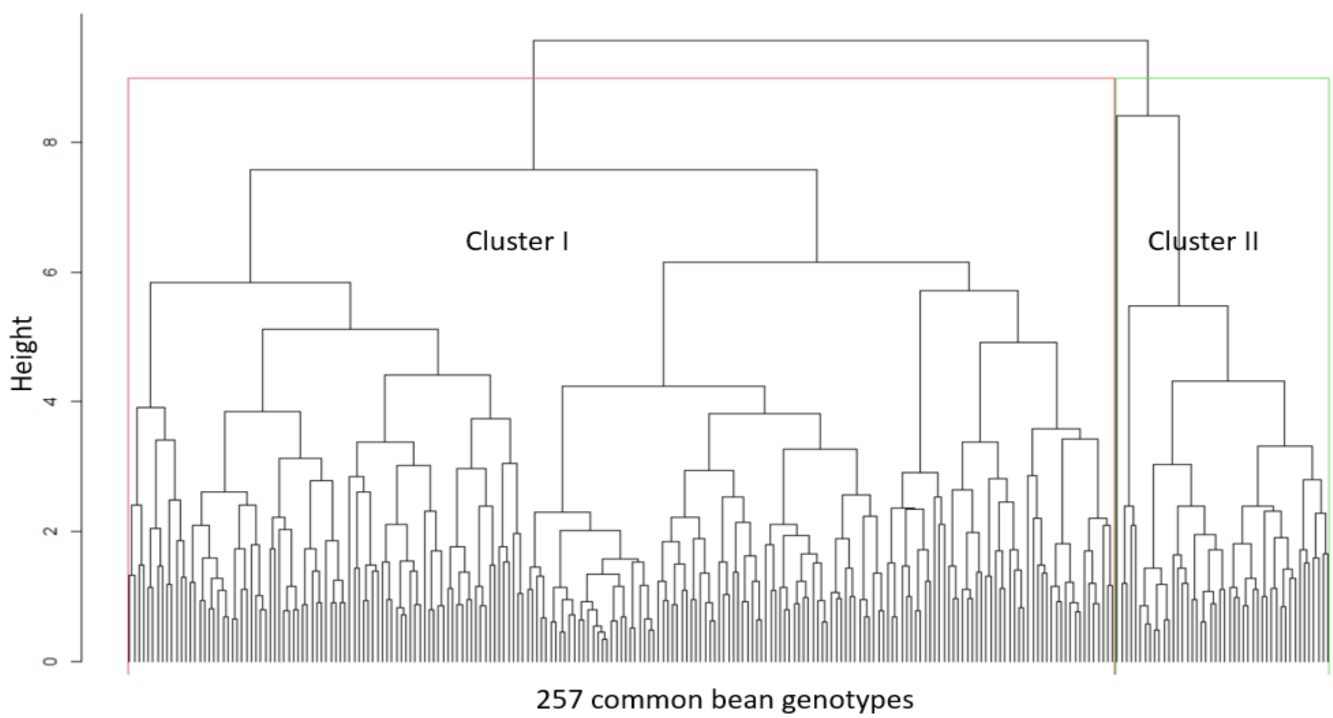

Figure 1. Dendrogram showing relationship among 257 common bean genotypes evaluated in this study.
Source: Author's work.

genotypes, which had the highest pod length, seed weight, and yield with a mean of 10.4 cm, 45.5 g and 1322.1 $kgha^{-1}$, respectively. The second group constituted 17.9% of the genotypes and had the highest days to flowering, days to maturity, number of pods per plant and number of seeds per pod of 39.7 days, 84.1 days, 15.9, and 5.1 respectively (Figure 1).

Estimation of genetic variables for traits measured

The extent of variance components and heritability estimates of seven common bean traits are presented in Table 4. The phenotypic coefficient of variation ranged from 6.3% (days to maturity) to 51.4% (grain yield). Days to flowering and days to maturity recorded a low phenotypic coefficient of variation (0-10%) of 8.7 and 6.3%, respectively. On the other hand, pod length, seeds per pod, 100-seed weight, number of pods per plant, and grain yield showed a high phenotypic coefficient of variation (>20%) of 20.8, 22.8, 36.5, 43.6, and 51.4%, respectively (Table 4).

Genotypic coefficient of variation ranged from low (0-10%), moderate (10-20%) to high (>20%). Days to

Table 4. Estimation of genetic variables for seven agronomic traits for 257 common bean accessions grown at Juja in 2018 and 2019.

Components	DF (days)	DM (days)	Pods/plant (No.)	Pod length (cm)	Seed/Pod (No.)	100-Seed weight (g)	Yield (kg/ha)
Environmental variation	2.5	14.8	20.8	2.1	0.8	21.8	303046.0
Phenotypic variation	10.7	26.9	30.3	4.2	1.1	181.8	542948.4
Genetic variation	8.2	12.1	9.5	2.1	0.3	160.0	239902.4
Heritability (H^2) %	76.9	51.1	32.2	52.4	38.7	89.0	60.5
PCV %	8.7	6.3	43.6	20.8	22.8	36.5	51.4
GCV %	7.6	4.2	24.4	14.6	12.6	34.3	40.0

H^2= Broad sense heritability, PVC=Phenotypic coefficient of variation, GCV=Genotypic coefficient of variation, DF=Days to flowering, DM=Days to maturity.
Source: Author's work.

Table 5. Pearson correlation coefficient among seven agronomic traits for 257 common bean accessions grown at Juja in 2018 and 2019.

Correlation	DF (days)	DM (days)	Pods/Plant (no.)	Pod length (cm)	Seed/Pod (no.)	100-Seed weight (g)
DM	0.73**					
Pods/Plant	0.36**	0.26**				
Pod length	-0.02^{ns}	0.05^{ns}	-0.34**			
Seed/Pod	0.43**	0.34**	0.50**	0.08^{ns}		
100-Seed weight	-0.45**	-0.28**	-0.66**	0.51**	-0.65**	
Yield (kg/ha)	-0.04^{ns}	0.03^{ns}	0.17**	0.34**	0.04ns	0.31**

*,**=Significant at 0.05 and 0.01 probability levels respectively, DF=Days to flowering, DM= Days to maturity.
Source: Author's work.

maturity and days to flowering had a low genotypic coefficient of variation of 4.2 and 7.6%, respectively, while the number of seeds per pod and pod length had a moderate genotypic coefficient of variation of 12.6 and 14.6%, respectively. High genotypic coefficients of variation were recorded for the number of pods per plant, 100-seed weight, and grain yield of 24.4, 34.3, and 40.0%, respectively (Table 4).

Grain yield, days to flowering and 100-seed weight recorded high broad-sense heritability (H^2>0.6) of 60.5, 76.8, and 89.0%, respectively. In contrast, the number of pods per plant, number of seeds per pod, days to maturity, and pod length showed moderate broad sense heritability (H^2=0.3-0.6) of 32.2, 38.7, 51.1, and 52.4%, respectively (Table 4).

Correlation between seed yield and yield components

The correlation coefficients among days to flowering, days to maturity, number of pods per plant, number of seeds per pod, 100-seed weight, and grain yield are presented in Table 5. A significant (P≤0.05) strong and positive correlation (0.73) was recorded between days to flowering and days to maturity. A moderate positive and significant association was revealed between pod length and 100-seed weight (0.51), between pods per plant and seed per pod (0.5) and between days to flowering and seeds per pod (0.43). \

A significant positive but weak relationship was revealed between days to flowering and pods per plant (0.36), between days to maturity and number of seeds per pod (0.34), between pod length and grain yield (0.34), between 100 seed weight and grain yield (0.31), and between days to maturity and pods per plant (0.26). A significant extremely weak positive correlation of 0.17 was recorded between pods per plant and grain yield at P≤0.05 (Table 5).

A significant (P≤0.05) strong negative correlation was recorded between the number of pods per plant and 100-seed weight (-0.66) and between the number of seeds per pod and 100-seed weight (-0.65) among accessions. Furthermore, a significant moderate and negative relationship between days to maturity and 100-seed weight (-0.45) was recorded.

Finally, a significant but weak negative association between pods per plant and pod length (-0.34) and between days to maturity and 100-seed weight (-0.28) were also recorded (Table 5).

Table 6. Mean values of agronomic traits for top 10, bottom 5 and checks of common bean accessions grown in Juja in 2018 and 2019 ranked based on grain yield.

Name	DF (days)	DM (days)	Pods/plant (No.)	Pod length (cm)	Seed/Pod (No.)	100-Seed weight (g)	Yield (Kgha^{-1})
High yielding							
KNB0106	38.4	84.1	21.5	10.2	5.2	41.1	4641.9
GBK035398	38.9	82.3	13.3	12.1	5.0	51.0	2758.1
NUA700	39.6	86.6	15.0	11.7	3.6	43.6	2668.8
GBK035092	38.9	80.6	13.7	10.7	5.1	41.6	2523.1
GBK035025	39.1	80.6	12.7	11.5	4.3	43.6	2398.1
GBK035051	37.3	83.8	15.3	10.7	5.3	25.9	2367.5
KNB0107	34.9	81.8	16.0	10.4	5.0	26.9	2365.6
NUA637	35.4	82.0	10.3	14.5	5.0	52.4	2361.9
GBK035447	42.1	86.0	14.1	12.2	5.0	40.5	2357.5
NUA662	38.8	84.3	11.7	10.5	3.6	59.0	2335.6
Low yielding							
GBK035431	39.1	84.6	16.6	8.6	5.1	21.6	370.6
GBK035023	43.3	88.6	5.9	11.7	3.9	50.1	325.6
GBK035295	37.9	82.1	14.1	9.2	5.4	20.4	288.8
GBK035320	39.4	78.0	8.8	8.9	4.5	21.4	250.0
GBK035350	37.0	84.5	14.7	6.9	4.0	20.0	220.6
Commercial varieties							
GLP×92	35.1	83.6	13.6	9.2	5.0	41.0	1995.0
GLP2	37.3	79.1	7.3	12.6	4.5	59.8	1422.5
GLP24	38.4	83.8	20.2	9.9	5.6	23.8	1492.5
GLP1127a	36.3	79.3	10.6	12.1	4.5	43.9	1268.1
Overall mean	**37.8**	**82.0**	**12.6**	**9.9**	**4.6**	**36.9**	**1267.0**
LSD accessions	1.9**	3.4**	5.1**	1.4**	0.7**	4.4**	322.5**
LSD seasons	0.2**	0.4**	0.6**	0.2**	0.1**	0.5**	65.2**
CV%	5.2	4.2	35.5	14.0	16.5	12.1	32.3

*,**=Significant at 0.05 and 0.01 probability levels respectively, LSD=Least significance difference, CV=Coefficient of variation, DM= Days to maturity.
Source: Author's work.

Means for days to flowering, days to maturity, number of pods per plant, pod length, number of seeds per pod, 100-seed weight and seed yield

There were highly significant (P≤0.05) differences for all the traits studied among the 257 common bean accessions. The seasonal and the interaction effect between season and common bean accessions also significantly influenced all the evaluated traits. For example, the mean for days to flowering, days to maturity, 100-seed weight, and grain yield were higher in long rain seasons than in short rain seasons. However, the average pods per plant and pod length were higher during the short rain than in long rain seasons (Supplementary Table 1).

The period between flowering and maturity ranged from 35.5 (GBK035394) to 53.6 (GBK035007) days with a mean 44.1 days, this grain filling period varied from 41.9 (GLP 2) to 48.5 days (GLP×92) among the commercial varieties. Among the commercial varieties evaluated in this study, GLP×92 was the earliest to flower (35.1 days) and had the highest grain yield (1995 kg/ha). On the other hand, GLP2 was the earliest to mature (79.1 days) had the longest pods (12.6cm) and the highest 100-seed weight (59.8g), while GLP24 had the highest number of pods per plant (20.2) and the highest number of seeds per pod (5.6) (Table 6). However, 57 accessions flowered earlier than GLP×92, 69 accessions matured earlier GLP2 and 20 accessions out yielded GLP2 in grain yield (Supplementary Table 1). Nineteen accessions had shorter duration to maturity and higher yielded than the earliest maturing commercial variety GLP2 (Table 7 and

Table 7. Mean values of agronomic traits for top 10, bottom 5 and checks of common bean accessions grown in Juja in 2018 and 2019 ranked based on maturity.

Name	DF (days)	DM (days)	Pods/Plant (No.)	Pod length (cm)	Seed/Pod (No.)	100-Seed weight (g)	Yield ($kgha^{-1}$)
Early maturing							
GBK034983	34.4	73.3	12.4	10.3	5.1	27.8	1343.1
GBK034989	37.8	74.0	11.1	9.2	4.3	31.6	1673.1
GBK035394	38.8	74.3	12.6	8.4	4.8	18.1	1076.3
GBK035322	35.0	74.3	12.1	9.3	4.7	31.3	686.9
GBK035284	34.0	74.5	13.1	9.9	5.0	31.5	1506.9
GBK035337	34.5	75.0	14.8	8.3	4.7	32.1	1470.6
GBK035338	36.5	75.1	19.3	9.3	5.0	18.8	1203.1
GBK035378	36.5	75.3	14.4	7.8	4.4	27.3	1340.6
GBK035318	33.8	75.4	10.9	10.5	4.1	45.6	539.4
GBK035078	33.9	75.8	9.5	8.1	3.6	46.3	988.8
Late maturing							
GBK034966	40.5	89.3	18.7	9.4	5.8	21.4	1043.8
GBK035381	40.0	89.9	12.4	10.6	5.5	26.9	1393.1
GBK035377	41.0	90.1	11.7	10.7	5.4	25.5	561.9
GBK034981	38.4	91.3	14.8	8.8	5.4	17.5	1208.8
GBK035007	37.8	91.4	7.7	11.0	4.2	47.1	945.6
Commercial varieties							
GLP×92	35.1	83.6	13.6	9.2	5.0	41.0	1995.0
GLP2	37.3	79.1	7.3	12.6	4.5	59.8	1422.5
GLP24	38.4	83.8	20.2	9.9	5.6	23.8	1492.5
GLP1127a	36.3	79.3	10.6	12.1	4.5	43.9	1268.1
Mean	**37.8**	**82.0**	**12.6**	**9.9**	**4.6**	**36.9**	**1267.0**
LSD accessions	1.9**	3.4**	5.1**	1.4**	0.7**	4.4**	322.5**
LSD seasons	0.2**	0.4**	0.6**	0.2**	0.1**	0.5**	65.2**
CV%	5.2	4.2	35.5	14.0	16.5	12.1	32.3

*,**=Significant at 0.05 and 0.01 probability levels respectively, LSD=Least significance difference, CV=Coefficient of variation, DF=Days to flowering, DM=Days to maturity.
Source: Author's work.

Supplementary Table 1).

Mean grain yields for common bean seed classes

The average grain yield for various seed classes evaluated in this study ranged from 1535.7 kg/ha (Pinto) to 951.4 kg/ha (Navy). Pinto, sugars, calima, small reds, large reds, and purples seed classes had the higher yields (>1370 kg/ha), while medium white, brown and tan, cariocas, yellow, blacks, and navy seed classes had lower yields of 1200 kg/ha and below (Table 8).

Mean grain yields for large, medium, and small-seeded common bean lines

The results revealed that the average grain yields varied with the seed size of the accessions, the large-seeded (>40 g) accessions had the highest yield of 1406.5 kg/ha, followed by the medium-sized (25-40 g) with an average of 1230.9 kg/ha, lastly, small-seeded (<25 g) had the lowest mean yields of 1039.3 kg/ha (Table 8).

Mean grain yields for bush, semi climber, and climbing common bean lines

The result shows that the mean grain yield varied with the growth habit of the accessions, accessions with climbing growth habit had the highest average grain yields of 1644.6 kg/ha, followed by semi climbers with an average yield of 1289.8 kg/ha and lastly, bush types had the lowest yields of 1102.3 kg/ha (Table 8).

Table 8. Mean grain yield for common bean accessions with different growth habits and seed sizes grown at Juja in 2018 and 2019.

Trait	Description	Number of accessions	Grain yield (kgha^{-1})		
			Long rain season	Short rain season	Mean
Growth habit					
Type I&II	Bush bean and upright short vine	124	1382.2	822.4	1102.3
Type III	Vine type	84	1565.5	1014.1	1289.8
Type IV	Climbing type	49	1835.6	1453.6	1644.6
Seed size					
Large	>40g for 100 seeds	127	1721.1	1091.8	1406.5
Medium	25-40g for 100 seeds	62	1452.8	1009.0	1230.9
Small	<25g for 100 seeds	68	1237.9	840.6	1039.3
Market classes					
Pintos	GLPx92 type	22	1765.2	1306.3	1535.7
Sugars	Cream, can be speckled	39	1786.0	1192.6	1489.3
Calima	Rosecoco type	25	1986.5	991.9	1489.2
Small reds	Red haricot type	15	1585.9	1320.4	1453.1
Large reds	Canadian wonder type	17	1612.6	1133.5	1373.0
Purples	Mwezimoja type	11	1621.5	1122.1	1371.8
Medium whites	Medium and large whites	13	1536.3	864.0	1200.1
Brown and tan	Brown and orange	19	1235.1	981.5	1108.3
Cariocas	Red and Red specks	28	1379.8	781.4	1080.6
Yellow	Yellow coloured	8	1273.6	874.7	1074.2
Blacks	Black coloured	23	1303.8	727.0	1015.4
Navy	Small whites	37	1129.0	773.8	951.4

Source: Author's work.

DISCUSSION

In the current study, grain yield and number of pods per plant had the highest coefficient of variation, indicating a strong environmental influence among the genotypes evaluated for these traits. Similar results were obtained for seed yield (50.7%) and the number of pods per plant (38.9) in a previous study conducted by Negahi et al. (2014) using 284 genotypes. Cluster analysis grouped the common bean genotypes into two major groups. The cluster with majority (82.1%) of genotypes contained the large-seeded (> 45 g 100-seed weight) genotypes of Andean gene pool which are reported to be adapted to higher altitude and cooler environments. The other groups consisted of small-seeded accessions with a mean 100-seed weight of 23.9 g of Mesoamerican gene pool which is adapted to lower altitudes and higher temperatures (Beebe et al., 2011).

The coefficient of variation is a scale that can be used to compare the extent of variation of different traits with different measurement units. According to Burton and de Vane (1953), phenotypic and genotypic coefficients of variation are categorized as 0-10% low, 10-20% high, and above 20% as high. The results show high genotypic coefficients of variations for 100-seed weight, the number of pods per plant, and grain yield, which indicates high genetic variation in these traits among the common bean accessions evaluated. Similar results have been reported for number pods per plant, 100-seed weight, and grain yield by Negahi et al. (2014), who observed a high phenotypic coefficient of variation of 53.3, 38.9, and 50.7% for 100-seed weight, the number of pods per plant, and seed yield, respectively. On the contrary, a low genotypic coefficient of variation for 100-seed weight, number of pods per plant, and seed yield of 4.6, 4.67, and 2.2%, respectively, have also been reported in a previous study that evaluated 52 common bean landraces. The low genotypic coefficient could be attributed to low genetic diversity among the accessions used in the study (Anunda et al., 2019).

The significant seasonal differences for various traits between long and short rains are due to differences in environmental conditions, especially temperatures and rainfall. Lower temperatures prevail during long rain season, causing a prolonged vegetative state that delay flower and maturity. Heavy rainfall experienced during long rains adversely affects flower fertilization, resulting in reduced pod sets hence the lower number of pods in some cultivars during these seasons. On the other hand, short rain seasons tend to have higher temperatures that lead to early termination of the vegetative state and initiation of the reproductive phase (Mbugua et al., 2006). Genotypes that flower and mature early tend to be more adapted to environment of growth than late maturing genotypes (Amanullah et al., 2006). In this study, nineteen accessions were found to combine early maturity and reasonable yield higher than that of earliest maturing commercial variety GLP2.

Variety GLP 2 was the earliest to mature among the commercial varieties, however, there were 19 bean accessions that had higher seed yield and matured earlier than this variety. These bean accessions are ideal for cultivation in areas with a short rainy season. On the other hand, the variety GLP×92 was the earliest to flower, the latest to mature, and had the highest seed yield among the commercial varieties. Therefore, GLP×92 had a prolonged grain filling period that led to higher seed yield. Beebe et al. (2013) found that that drought tolerant lines with improved yields also presented shorter period to maturity.

The high yielding potential of climbing common bean was revealed in this study. However, climbing genotypes are labor-intensive as they require staking and may not be ideal for mixed cropping. The results agree with Wortmann et al. (1998) who reported that common beans with climbing growth habits are higher-yielding and hence ideal for small-scale farmers with a limited size of land in highland areas. Oppositely, the bush types are preferred because they do not require support and are early maturing, hence convenient for commercial production (Wortmann et al., 1998; Okii et al., 2014).

The results show that pinto, sugars, calima, small reds, large reds, and purples seed classes were more adapted to the environment in which the experiment was conducted compared to medium white, brown and tan, cariocas, yellows, blacks, and navy seed classes. It has been reported that consumer preference for common beans depends on seed size and color among other characteristics. In eastern Africa, the calima seed type (red speckled) is highly popular and accounts for about 22% of common bean production. Medium and small reds follow in consumer preference accounting for approximately 20% of the production. Large reds including red kidney rank third in popularity accounting for about 10% of common beans produced, navy, whites, purples, and black follow in popularity, respectively (Wortmann et al., 1998). The results show that the popular seed classes in the region were the highest yielding in this study, which could have resulted from continuous selection by local common bean farmers that improved their adaptability.

Common bean varieties vary in seed size, those that weigh less than 25 g per 100 seeds are classified as small-seeded while those that range from 25 to 40 g are classified as medium-sized, and those that weigh more than 40 g are classified as large-seeded (Rau et al., 2010; Lei et al., 2020). The result in this study indicates that large-seeded accessions are more adapted in this region, unlike the medium and small-seeded genotypes. Based on seed size, the common bean has been categorized into two distinct centers of origin, namely Mesoamerican and Andean gene pools (Blair et al., 2007; Burle et al., 2010). Andean gene pool is generally large-seeded and adapted to relatively higher altitudes and lower temperatures. In contrast, the Mesoamerican gene pool is small-seeded and adapted to lower altitudes and higher temperatures (Beebe et al., 2011).

Heritability estimates indicate how much variation in a trait can be attributed to genetic variation, which helps breeders to select based on the phenotypic performance of a trait. Based on the categorization of heritability by Johnson et al. (1955), the traits days to flowering, 100-seed weight, and grain yield traits recorded a high broad-sense heritability (>60%). This indicates that the performance of these traits was majorly due to genetic differences and could be improved through selection based on the trait itself. Yohannes et al. (2020) reported a high broad-sense heritability of days to maturity and 100-seed weight of 86.7 and 95.3%, respectively, and a moderate broad-sense heritability for days to flowering and number of seeds per pod of 40, and 51.6%, respectively.

Grain yield is a polygenic trait that is conditioned by three yield components, the number of pods per plant, the number of seeds per pod, and seed weight (Kamfwa et al., 2015). Consequently, the knowledge of the association between these seed yield attributes may help in selecting an excellent donor to improve this trait through indirect selection. A target trait can be improved through indirect selection via other traits. A strong positive relationship (0.73) between days to flowering and days to maturity indicates that days to flowering can be used to predict days to maturity for common bean accessions. Strongly associated traits are usually under the influence of the same gene or genes located close together on the chromosome and can both be selected simultaneously (Lobo, 2008). Days to flowering have been reported to be under the control of dominance and additive gene effect with the dominance effect being lower, and when present it reduces the number of days to flowering (Mendes et al., 2008). A similar correlation result (0.7) between days to flowering and days to maturity was reported in a previous study conducted by Kamfwa et al. (2015).

The weak and moderate positive correlation between days to flowering and number of pods per plant (0.36) and between days to flowering and number of seeds per pod (0.43) indicates that the number of pods per plant and number of seeds per pod is, to an extent, influenced by duration to flowering or time of flowering. For a crop that is largely self-pollinated like the common bean, pollination vectors may not be a limiting factor but the survival of pods and seeds after pollination may be affected by the competition of photosynthetic assimilates, soil nutrients, and water. These results agree with a previous study conducted by Marzooghian et al. (2014), who reported a positive correlation between days to flowering with both the number of pods per plant (0.36) and the number of seeds per pod (0.29).

The significant positive but weak relationship between grain yield and number of pods per plant (0.17), pod length (0.34) and 100-seed weight (0.31) indicate that these traits influence grain yields and should be put into consideration during selection to improve grain yield. Strong positive correlations between seed yield per plant and the number of pods per plant (0.67) (Anunda et al., 2019) have also been reported. A significant correlation of 0.51 between 100-seed weight and pod length suggests that large-seeded genotypes tend to have longer pods. Similar correlation result of 0.48 between 100-seed weight and pod length was reported by Okii et al. (2014).

A significant strong negative correlation between 100-seed weight and the number of pods per plant and between 100-seed weight and number of seeds per pod indicate compensation among yield components (Adams 1967). This negative association between yield components means that selecting for a greater number of pods per plant would lead to small-seeded plants, and selection for large-seeded genotypes would lead to plants with low seed locules per pod. It is critical to understand the nature of this negative relationship if it is independent of competition or due to competition for a limited resource.

Similar negative correlation results between 100-seed weight with both number of pods per plant and number of seeds per pod were reported by Negahi et al. (2014) and Kamfwa et al. (2015). However, Kamfwa et al. (2015) reported weak negative correlation between seed weight and the number of pods per plant (-0.17) and between the number of seeds per plant (-0.38) and days to maturity (-0.27).

Conclusion

The results showed high phenotypic and genotypic variation for 100-seed weight, the number of pods per plant, and grain yield. Higher yields were obtained during long rain seasons.

The traits days to flowering, 100-seed weight, and grain yield showed high broad-sense heritability. Grain yield had weak positive correlations with the number of pods per plant, pod length, and 100-seed weight. Large-seeded, climbing, and popular (pinto, calima, small reds, and purples) bean accessions had higher yields.

The study identified nineteen bean accessions that combined early maturity and high-yielding traits.

Common bean accessions evaluated in this study showed heritable variation that could be exploited in breeding programs.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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SUPPLEMENTARY MATERIALS

Supplementary Table 1. Mean values of agronomic traits for all common bean accessions grown in Juja in 2018 and 2019.

Name	Days to flowering (days)			Days to maturity (days)			Pods/Plant (No.)			Pod length (cm)			Seed/Pod (No.)			100 seed weight (g)			Yield kgha^{-1}		
	LR	SR	Mean	LR	SR	Mean	LR	SR	Mean	LR	SR	Mean	LR	SR	Mean	LR	SR	Mean	LR	SR	Mean
KNB0106	39.3	37.5	38.4	85.3	83.0	84.1	19.0	22.8	21.5	10.0	10.5	10.2	5.3	5.2	5.2	41.5	40.8	41.1	4926.3	4357.5	4641.9
GBK035398	38.8	39.0	38.9	82.0	82.5	82.3	12.0	14.0	13.3	12.3	12.0	12.1	5.5	4.4	5.0	53.3	48.8	51.0	3358.8	2157.5	2758.1
NUA700	40.8	38.5	39.6	88.0	85.3	86.6	12.5	16.3	15.0	11.5	11.9	11.7	3.5	3.8	3.6	42.5	44.8	43.6	2967.5	2370.0	2668.8
GBK035092	38.8	39.0	38.9	82.0	79.3	80.6	14.0	13.5	13.7	10.3	11.1	10.7	5.3	4.9	5.1	37.5	45.8	41.6	2765.0	2281.3	2523.1
GBK035025	38.5	39.8	39.1	82.5	78.8	80.6	12.5	12.8	12.7	11.3	11.8	11.5	5.0	3.6	4.3	44.3	43.0	43.6	3125.0	1671.3	2398.1
GBK035051	37.5	37.0	37.3	83.5	84.0	83.8	13.5	16.3	15.3	11.3	10.2	10.7	5.5	5.1	5.3	25.5	26.3	25.9	2845.0	1890.0	2367.5
KNB0107	35.0	34.8	34.9	83.8	79.8	81.8	12.5	17.8	16.0	9.5	11.3	10.4	4.8	5.2	5.0	24.8	29.0	26.9	1721.3	3010.0	2365.6
NUA637	35.8	35.0	35.4	83.0	81.0	82.0	11.5	9.8	10.3	14.3	14.7	14.5	5.3	4.8	5.0	54.5	50.3	52.4	3078.8	1645.0	2361.9
GBK035447	42.3	42.0	42.1	87.0	85.0	86.0	13.0	14.6	14.1	12.0	12.4	12.2	5.8	4.3	5.0	40.8	40.3	40.5	2913.8	1801.3	2357.5
NUA662	39.5	38.0	38.8	84.5	84.0	84.3	9.0	13.1	11.7	10.8	10.2	10.5	4.0	3.2	3.6	62.8	55.3	59.0	3170.0	1501.3	2335.6
NUA640	39.8	39.0	39.4	83.5	80.0	81.8	11.5	12.9	12.4	10.5	9.3	9.9	4.5	3.2	3.8	57.5	56.0	56.8	3241.3	1223.8	2232.5
GBK035395	38.3	38.3	38.3	84.8	85.5	85.1	12.0	13.5	13.0	8.8	8.8	8.8	5.3	4.3	4.8	31.8	33.0	32.4	2773.8	1648.8	2211.3
Tasha	39.3	35.5	37.4	84.5	81.5	83.0	16.0	15.5	15.7	8.8	9.9	9.3	3.3	3.9	3.6	41.8	49.8	45.8	2631.3	1717.5	2174.4
NUA631	36.5	36.8	36.6	79.0	80.3	79.6	10.0	10.2	10.1	10.8	10.4	10.6	4.5	3.6	4.0	60.5	51.5	56.0	2846.3	1433.8	2140.0
KNB0101	39.3	38.3	38.8	85.0	80.0	82.5	15.5	19.9	18.4	9.5	10.7	10.1	5.3	6.3	5.8	23.3	25.8	24.5	2417.5	1747.5	2082.5
GBK035429	38.0	39.0	38.5	85.3	86.8	86.0	26.0	14.4	18.3	9.5	9.4	9.4	5.8	5.2	5.5	30.5	27.0	28.8	2117.5	2011.3	2064.4
KMT0106	36.5	34.3	35.4	78.5	82.0	80.3	6.0	8.6	7.7	13.3	13.8	13.5	4.8	4.1	4.4	64.5	62.3	63.4	1993.8	2111.3	2052.5
GBK035442	41.5	39.5	40.5	87.3	81.8	84.5	10.0	13.2	12.1	12.0	11.9	12.0	5.0	3.8	4.4	52.0	49.0	50.5	2320.0	1776.3	2048.1
NUA692	38.8	37.0	37.9	84.8	83.5	84.1	11.5	12.2	11.9	11.5	10.7	11.1	4.3	3.4	3.8	57.8	54.8	56.3	2860.0	1183.8	2021.9
GBK035090	36.8	37.3	37.0	82.8	79.8	81.3	10.5	9.4	9.8	10.8	11.3	11.0	4.5	4.3	4.4	41.0	38.8	39.9	2588.8	1415.0	2001.9
GLPx92	34.5	35.8	35.1	85.5	81.8	83.6	13.5	13.6	13.6	8.5	10.0	9.2	5.3	4.8	5.0	42.8	39.3	41.0	2306.3	1683.8	1995.0
KMT0102	36.8	35.5	36.1	83.0	77.5	80.3	7.0	15.2	12.4	13.3	13.4	13.3	5.0	4.9	5.0	48.8	46.3	47.5	2206.3	1763.8	1985.0
GBK035368	41.8	38.3	40.0	86.0	82.5	84.3	19.5	24.3	22.7	9.3	9.2	9.2	5.3	5.8	5.5	15.3	17.0	16.1	1992.5	1951.3	1971.9
KMT0109	35.0	34.0	34.5	83.5	80.8	82.1	12.5	10.0	10.8	14.3	14.5	14.4	4.8	4.7	4.7	64.8	64.0	64.4	2173.8	1672.5	1923.1
NUA666	38.8	35.3	37.0	86.5	80.5	83.5	13.0	13.3	13.2	14.0	12.2	13.1	5.0	4.4	4.7	55.8	47.3	51.5	2206.3	1628.8	1917.5
GBK035063	37.8	39.8	38.8	84.8	88.5	86.6	11.0	10.7	10.8	11.0	11.4	11.2	5.0	4.3	4.7	49.8	46.3	48.0	2417.5	1391.3	1904.4
GBK034999	37.5	39.0	38.3	80.8	77.3	79.0	21.5	22.9	22.4	7.8	8.1	7.9	5.5	5.1	5.3	25.3	23.0	24.1	1962.5	1813.8	1888.1
GBK034983	37.0	36.5	36.8	79.0	76.3	77.6	17.5	30.2	25.9	8.3	8.4	8.3	5.0	4.7	4.8	28.0	25.3	26.6	2363.8	1406.3	1885.0
GBK035085	36.8	35.8	36.3	81.3	80.3	80.8	8.0	9.4	8.9	12.5	14.0	13.3	4.5	3.5	4.0	67.8	70.5	69.1	1978.8	1771.3	1875.0
GBK035280	41.3	42.8	42.0	85.0	88.0	86.5	16.5	18.8	18.0	9.3	9.7	9.5	5.5	5.4	5.5	20.0	21.3	20.6	2206.3	1540.0	1873.1
GBK035434	41.0	39.3	40.1	80.0	81.3	80.6	18.0	11.6	13.7	10.8	11.3	11.0	4.5	4.1	4.3	51.8	50.0	50.9	2577.5	1155.0	1866.3
KMT0115	40.5	40.0	40.3	86.5	86.3	86.4	11.5	10.3	10.7	11.5	11.8	11.6	4.5	3.7	4.1	52.3	52.3	52.3	1937.5	1783.8	1860.6
NUA654	41.5	37.8	39.6	87.5	83.5	85.5	12.5	11.6	11.9	12.8	12.8	12.8	4.5	4.9	4.7	46.8	47.5	47.1	1966.3	1750.0	1858.1
GBK035304	36.5	38.3	37.4	78.3	77.0	77.6	10.5	15.4	13.8	14.5	13.7	14.1	5.8	4.4	5.1	47.8	41.8	44.8	2266.3	1430.0	1848.1
GBK035456	39.8	38.8	39.3	84.0	84.0	84.0	14.0	16.4	15.6	10.5	11.0	10.7	4.3	3.9	4.1	50.0	44.0	47.0	2430.0	1262.5	1846.3
GBK035285	39.0	36.8	37.9	83.3	80.3	81.8	11.5	22.9	19.1	8.0	8.4	8.2	4.3	4.4	4.3	33.5	31.0	32.3	2115.0	1476.3	1795.6

Supplementary Table 1. Contd.

GBK035276	36.0	36.5	36.3	84.0	86.8	85.4	20.5	16.5	17.8	8.5	9.4	8.9	4.3	4.7	4.5	33.5	36.5	35.0	1752.5	1781.3	1766.9
GBK035028	38.3	40.0	39.1	83.5	85.3	84.4	11.5	13.1	12.6	10.3	10.4	10.3	5.3	4.8	5.0	29.0	31.0	30.0	1890.0	1638.8	1764.4
KMT0104	34.3	35.8	35.0	80.5	80.3	80.4	12.5	10.4	11.1	12.0	11.4	11.7	5.3	3.8	4.5	52.3	48.8	50.5	2088.8	1435.0	1761.9
GBK035370	40.0	38.8	39.4	86.8	87.0	86.9	17.5	13.2	14.6	9.3	9.2	9.2	6.0	5.0	5.5	19.8	22.8	21.3	2302.5	1146.3	1724.4
GBK035448	41.5	41.5	41.5	86.5	84.5	85.5	14.0	14.3	14.2	9.3	9.8	9.5	6.0	4.8	5.4	23.3	25.5	24.4	1826.3	1603.8	1715.0
GBK035080	41.5	39.0	40.3	82.0	81.5	81.8	10.0	8.3	8.9	10.0	9.2	9.6	4.8	4.0	4.4	48.5	42.8	45.6	2295.0	1126.3	1710.6
KMT0112	41.3	40.8	41.0	87.5	87.0	87.3	9.5	10.0	9.8	12.0	12.1	12.1	4.5	4.3	4.4	57.3	55.8	56.5	1975.0	1443.8	1709.4
GBK035376	33.5	34.8	34.1	77.3	77.3	77.3	8.0	10.3	9.5	14.0	10.9	12.5	5.8	4.9	5.3	49.0	46.3	47.6	2081.3	1323.8	1702.5
GBK035416	40.5	37.8	39.1	83.5	84.5	84.0	17.5	13.2	14.6	9.0	9.4	9.2	6.0	5.1	5.5	30.0	31.3	30.6	1775.0	1581.3	1678.1
GBK035084	39.5	39.5	39.5	85.5	85.3	85.4	14.0	15.8	15.2	11.0	10.8	10.9	6.8	5.8	6.3	19.8	24.5	22.1	1820.0	1533.8	1676.9
GBK034989	37.0	38.5	37.8	72.0	76.0	74.0	9.5	11.8	11.1	10.0	8.5	9.2	4.8	3.8	4.3	33.5	29.8	31.6	2258.8	1087.5	1673.1
GBK035367	36.5	33.8	35.1	83.5	79.8	81.6	12.5	13.2	12.9	12.3	13.2	12.7	5.0	4.5	4.8	48.3	42.3	45.3	1762.5	1557.5	1660.0
GBK035086	38.5	38.5	38.5	79.5	75.8	77.6	9.0	10.1	9.7	9.0	9.6	9.3	4.8	4.1	4.4	40.3	39.3	39.8	2248.8	1060.0	1654.4
NUA596	35.8	35.5	35.6	82.3	83.0	82.6	10.0	11.2	10.8	9.5	11.3	10.4	3.8	4.4	4.1	45.5	41.3	43.4	1913.8	1357.5	1635.6
KMT0110	34.8	35.0	34.9	77.8	78.5	78.1	7.5	10.0	9.2	11.3	13.1	12.2	4.3	3.8	4.0	56.5	54.0	55.3	1941.3	1321.3	1631.3
GBK035439	35.5	36.3	35.9	83.3	82.8	83.0	10.5	7.9	8.8	12.5	12.5	12.5	4.3	3.8	4.0	65.0	62.8	63.9	2496.3	765.0	1630.6
GBK034997	35.5	34.0	34.8	79.5	82.0	80.8	20.0	23.3	22.2	9.3	8.7	9.0	4.0	4.1	4.0	35.0	34.5	34.8	1402.5	1846.3	1624.4
NUA710	40.3	38.8	39.5	81.8	81.0	81.4	12.5	9.8	10.7	10.5	12.3	11.4	5.0	3.3	4.1	49.5	54.0	51.8	2138.8	1103.8	1621.3
GBK035043	34.3	37.8	36.0	82.8	81.3	82.0	14.0	12.3	12.9	11.5	11.4	11.5	4.8	3.8	4.3	44.0	44.3	44.1	2105.0	1133.8	1619.4
NUA695	37.5	36.8	37.1	83.3	78.5	80.9	7.5	11.8	10.3	11.8	11.1	11.4	5.0	3.0	4.0	47.8	51.5	49.6	2316.3	895.0	1605.6
GBK035310	39.0	35.5	37.3	86.5	82.3	84.4	13.5	15.2	14.6	7.5	8.7	8.1	4.3	4.1	4.2	45.8	44.0	44.9	1626.3	1577.5	1601.9
KMT0111	42.3	39.0	40.6	88.0	87.3	87.6	6.0	9.8	8.6	11.3	11.2	11.2	4.8	3.7	4.2	52.3	56.0	54.1	1858.8	1316.3	1587.5
GBK035392	42.3	39.5	40.9	88.0	83.5	85.8	10.0	18.9	15.9	10.3	11.0	10.6	7.5	5.9	6.7	21.8	25.0	23.4	1345.0	1825.0	1585.0
GBK035432	36.0	37.3	36.6	79.3	78.8	79.0	11.0	11.6	11.4	11.3	13.3	12.3	4.8	4.3	4.5	44.0	46.5	45.3	1857.5	1283.8	1570.6
GBK035278	41.5	37.5	39.5	83.8	85.0	84.4	14.0	15.8	15.2	9.8	10.0	9.9	6.3	4.6	5.4	27.5	29.5	28.5	1990.0	1138.8	1564.4
GBK034307	48.0	38.8	43.4	88.0	83.3	85.6	17.5	36.2	29.9	7.8	8.3	8.0	6.0	5.4	5.7	17.8	16.0	16.9	1747.5	1373.8	1560.6
GBK035036	40.8	38.0	39.4	83.0	84.8	83.9	14.0	15.3	14.9	11.0	10.6	10.8	6.8	6.3	6.5	20.8	24.5	22.6	1681.3	1437.5	1559.4
GBK035374	40.8	39.5	40.1	88.0	84.8	86.4	11.5	14.8	13.7	9.5	11.0	10.2	6.0	5.9	6.0	22.8	24.0	23.4	1863.8	1252.5	1558.1
GBK035384	34.3	34.5	34.4	81.0	80.0	80.5	9.0	11.3	10.6	14.8	14.7	14.7	5.5	4.9	5.2	50.0	46.3	48.1	1970.0	1126.3	1548.1
GBK035436	42.0	42.0	42.0	86.0	78.5	82.3	18.5	18.8	18.7	9.5	9.7	9.6	5.5	5.0	5.3	19.0	21.3	20.1	1495.0	1596.3	1545.6
NUA718	40.0	38.3	39.1	78.0	79.8	78.9	11.0	11.3	11.2	10.0	11.2	10.6	3.8	3.7	3.7	44.5	45.8	45.1	1803.8	1283.8	1543.8
NUA680	38.8	39.8	39.3	86.8	85.0	85.9	9.0	7.2	7.8	13.0	11.8	12.4	4.8	3.4	4.1	59.8	56.0	57.9	2182.5	902.5	1542.5
GBK035052	40.5	38.3	39.4	81.8	80.8	81.3	5.5	12.2	9.9	9.3	9.9	9.6	4.8	4.1	4.4	38.8	38.3	38.5	1888.8	1192.5	1540.6
GBK035450	43.0	38.5	40.8	86.0	84.0	85.0	14.0	12.3	12.9	10.5	10.0	10.3	6.8	5.3	6.0	23.3	24.3	23.8	1388.8	1690.0	1539.4
NUA612	32.8	33.0	32.9	77.5	79.5	78.5	12.0	9.4	10.3	8.0	7.6	7.8	4.0	3.3	3.6	49.3	48.0	48.6	2105.0	971.3	1538.1
NUAChelalang	37.8	39.3	38.5	80.3	84.0	82.1	8.0	10.3	9.5	9.3	11.3	10.3	3.3	3.8	3.5	52.5	48.8	50.6	2015.0	1041.3	1528.1
GBK034099	34.0	35.0	34.5	83.5	79.3	81.4	11.5	15.4	14.1	9.0	8.5	8.8	4.5	4.8	4.7	27.3	29.5	28.4	1132.5	1908.8	1520.6
NUA728	38.8	40.0	39.4	82.8	82.5	82.6	12.0	8.7	9.8	9.3	9.7	9.5	3.5	3.4	3.5	47.5	46.8	47.1	2151.3	872.5	1511.9
GBK035284	33.5	34.5	34.0	75.3	73.8	74.5	10.5	14.4	13.1	9.3	10.6	9.9	5.5	4.5	5.0	33.0	30.0	31.5	1871.3	1142.5	1506.9
GBK035279	43.5	43.5	43.5	86.5	88.0	87.3	18.5	25.7	23.3	10.3	9.3	9.8	6.0	5.2	5.6	20.8	22.5	21.6	1801.3	1193.8	1497.5
GLP24	38.8	38.0	38.4	82.3	85.3	83.8	16.0	22.3	20.2	10.0	9.7	9.9	5.5	5.8	5.6	24.0	23.5	23.8	2197.5	787.5	1492.5

Supplementary Table 1. Contd.

NUA739	37.8	36.8	37.3	80.8	81.3	81.0	12.0	8.8	9.8	11.0	11.4	11.2	4.5	4.4	4.5	45.8	48.0	46.9	1695.0	1281.3	1488.1
GBK035398	34.5	35.0	34.8	80.3	78.3	79.3	9.0	10.3	9.9	9.5	11.4	10.4	5.0	3.2	4.1	61.5	61.0	61.3	1283.8	1690.0	1486.9
GBK035001	34.3	35.0	34.6	77.5	74.5	76.0	14.5	16.4	15.8	9.8	7.4	8.6	4.8	3.8	4.3	25.8	32.0	28.9	2256.3	686.3	1471.3
GBK035381	33.8	34.3	34.0	79.8	76.0	77.9	11.0	10.0	10.3	13.3	13.3	13.3	4.8	4.2	4.5	57.0	49.8	53.4	1677.5	1265.0	1471.3
GBK035337	33.8	35.3	34.5	76.5	73.5	75.0	13.5	15.5	14.8	7.8	8.8	8.3	5.0	4.4	4.7	34.8	29.5	32.1	1573.8	1367.5	1470.6
GBK035400	36.8	39.8	38.3	86.8	85.8	86.3	19.0	20.1	19.7	10.0	8.5	9.3	4.8	4.8	4.8	15.0	17.3	16.1	1207.5	1720.0	1463.8
GBK034345	44.3	38.8	41.5	86.0	84.5	85.3	7.5	12.3	10.7	9.8	10.0	9.9	4.3	3.5	3.9	42.5	42.3	42.4	1605.0	1275.0	1440.0
GBK035073	33.5	33.0	33.3	80.3	78.0	79.1	10.5	8.6	9.2	10.3	9.0	9.6	4.5	3.7	4.1	50.3	44.0	47.1	1915.0	960.0	1437.5
GBK034996	37.8	37.3	37.5	87.3	80.8	84.0	21.5	17.7	18.9	8.0	8.3	8.1	5.3	4.7	5.0	29.3	26.8	28.0	1608.8	1265.0	1436.9
GBK035061	33.5	32.8	33.1	77.5	80.5	79.0	12.5	7.9	9.4	8.3	8.6	8.4	4.3	3.4	3.8	52.3	45.3	48.8	2045.0	823.8	1434.4
KMT0114	36.0	35.0	35.5	77.5	80.3	78.9	11.0	16.2	14.4	11.3	11.4	11.3	4.0	3.7	3.8	67.3	58.8	63.0	1510.0	1347.5	1428.8
GBK035006	35.0	34.0	34.5	76.0	77.5	76.8	7.5	12.0	10.5	13.8	14.8	14.3	5.0	5.0	5.0	48.5	47.3	47.9	1311.3	1541.3	1426.3
GLP2	37.3	37.3	37.3	78.0	80.3	79.1	7.0	7.4	7.3	12.0	13.1	12.6	4.3	4.8	4.5	60.3	59.3	59.8	2093.8	751.3	1422.5
GBK035425	34.5	35.0	34.8	77.5	76.8	77.1	8.0	7.8	7.9	13.3	12.7	13.0	5.3	4.2	4.7	57.3	47.0	52.1	1647.5	1180.0	1413.8
KMT0117	38.0	34.5	36.3	83.0	82.3	82.6	8.0	12.3	10.8	8.8	9.2	9.0	4.3	3.7	4.0	53.5	50.3	51.9	1710.0	1105.0	1407.5
GBK035446	41.5	39.0	40.3	88.0	85.5	86.8	8.0	9.3	8.9	11.0	11.0	11.0	4.8	4.7	4.7	45.8	40.8	43.3	1725.0	1073.8	1399.4
GBK035021	38.3	37.5	37.9	81.8	78.8	80.3	9.5	10.4	10.1	9.3	10.1	9.7	3.5	3.6	3.5	54.8	49.8	52.3	1481.3	1315.0	1398.1
GBK035005	41.3	42.0	41.6	86.5	86.8	86.6	14.0	17.7	16.4	10.8	9.4	10.1	5.5	5.1	5.3	20.3	23.8	22.0	1401.3	1390.0	1395.6
GBK035381	40.0	40.0	40.0	90.0	89.8	89.9	20.0	8.6	12.4	10.8	10.5	10.6	5.8	5.3	5.5	26.0	27.8	26.9	1930.0	856.3	1393.1
GBK035009	41.3	39.8	40.5	80.3	77.8	79.0	23.5	17.5	19.5	7.8	7.7	7.7	5.5	3.9	4.7	22.5	18.8	20.6	1762.5	991.3	1376.9
GBK035074	32.8	32.8	32.8	79.0	81.3	80.1	8.5	8.4	8.4	9.5	9.0	9.3	4.5	3.9	4.2	49.3	43.8	46.5	2210.0	540.0	1375.0
GBK035427	36.8	34.8	35.8	79.0	79.8	79.4	12.0	13.9	13.3	9.5	9.0	9.3	5.0	4.3	4.6	39.5	39.0	39.3	1861.3	885.0	1373.1
KMT0103	33.0	35.3	34.1	77.0	79.0	78.0	12.0	10.3	10.9	9.8	11.5	10.6	4.0	4.0	4.0	54.0	46.5	50.3	1768.8	942.5	1355.6
GBK035342	40.0	38.0	39.0	84.3	85.3	84.8	17.5	15.7	16.3	10.3	8.9	9.6	4.8	3.8	4.3	22.5	24.3	23.4	1562.5	1145.0	1353.8
GBK035072	41.8	37.0	39.4	77.0	80.0	78.5	8.5	9.2	8.9	10.3	9.7	10.0	4.8	4.4	4.6	44.3	44.8	44.5	1898.8	802.5	1350.6
GBK035310	42.5	39.3	40.9	86.8	78.3	82.5	19.0	18.7	18.8	9.0	7.9	8.5	5.5	4.8	5.1	24.8	17.3	21.0	1897.5	801.3	1349.4
GBK035449	43.3	42.0	42.6	86.3	87.3	86.8	17.5	14.3	15.3	7.8	8.4	8.1	5.3	5.2	5.2	20.3	21.5	20.9	1646.3	1047.5	1346.9
GBK034983	33.8	35.0	34.4	74.5	72.0	73.3	9.5	13.8	12.4	10.0	10.5	10.3	5.3	5.0	5.1	27.0	28.5	27.8	1316.3	1370.0	1343.1
GBK035378	36.3	36.8	36.5	74.8	75.8	75.3	13.0	15.1	14.4	8.5	7.2	7.8	5.3	3.5	4.4	27.8	26.8	27.3	1970.0	711.3	1340.6
GBK035428	35.3	34.8	35.0	86.5	80.5	83.5	13.5	15.9	15.1	7.5	9.2	8.3	5.0	4.2	4.6	45.3	39.0	42.1	1328.8	1346.3	1337.5
GBK035037	44.0	38.8	41.4	89.3	86.5	87.9	15.0	15.7	15.4	10.5	9.9	10.2	7.0	5.6	6.3	23.5	23.5	23.5	1252.5	1416.3	1334.4
GBK035033	37.5	38.0	37.8	78.3	76.8	77.5	10.5	10.4	10.4	11.8	11.5	11.6	4.5	3.5	4.0	44.3	42.8	43.5	1567.5	1090.0	1328.8
GBK034994	34.5	35.3	34.9	77.8	77.5	77.6	6.5	8.4	7.8	12.5	11.0	11.8	4.3	3.7	4.0	51.5	45.5	48.5	1772.5	880.0	1326.3
GBK035053	39.8	37.8	38.8	86.3	88.8	87.5	18.0	20.8	19.9	8.5	8.1	8.3	4.0	4.6	4.3	28.8	24.8	26.8	1425.0	1220.0	1322.5
GBK034978	38.3	35.0	36.6	82.8	79.0	80.9	14.0	17.7	16.4	10.3	9.0	9.6	5.0	4.7	4.8	25.8	26.3	26.0	1508.8	1132.5	1320.6
GBK035332	44.8	43.3	44.0	88.3	86.3	87.3	12.0	14.4	13.6	10.5	9.5	10.0	6.0	5.1	5.5	20.3	20.3	20.3	1630.0	1006.3	1318.1
GBK035406	44.0	39.5	41.8	85.8	86.0	85.9	12.5	16.3	15.0	9.8	10.4	10.1	6.8	5.5	6.1	25.3	25.5	25.4	1210.0	1422.5	1316.3
GBK035084	35.5	35.0	35.3	83.0	85.8	84.4	9.5	13.0	11.8	8.0	8.9	8.5	4.0	3.8	3.9	45.0	42.5	43.8	1341.3	1277.5	1309.4
NUA669	41.0	39.3	40.1	84.0	84.8	84.4	8.0	9.4	8.9	9.3	9.4	9.3	3.3	2.8	3.0	53.0	50.5	51.8	1881.3	720.0	1300.6
GBK035441	41.8	38.3	40.0	82.0	78.0	80.0	14.0	10.7	11.8	10.5	11.2	10.9	5.0	4.6	4.8	41.0	40.8	40.9	1833.8	766.3	1300.0
GBK035026	34.3	36.5	35.4	73.5	79.8	76.6	9.5	14.0	12.5	8.0	9.9	8.9	4.5	4.3	4.4	34.3	36.3	35.3	1343.8	1216.3	1280.0

Supplementary Table 1. Contd.

GBK035057	33.8	32.8	33.3	76.5	77.3	76.9	6.5	7.7	7.3	9.0	8.9	8.9	4.5	3.5	4.0	56.3	46.8	51.5	1615.0	943.8	1279.4
GBK035082	34.5	34.8	34.6	78.0	79.3	78.6	10.5	10.1	10.2	9.5	8.9	9.2	4.3	3.7	4.0	46.8	43.3	45.0	1551.3	1001.3	1276.3
GBK035050	43.3	41.3	42.3	85.0	80.5	82.8	8.5	8.3	8.4	9.0	8.9	9.0	4.5	3.9	4.2	42.3	39.8	41.0	1655.0	885.0	1270.0
GLP1127a	35.3	37.3	36.3	80.8	77.8	79.3	15.5	8.1	10.6	11.5	12.8	12.1	4.3	4.8	4.5	45.8	42.0	43.9	1631.3	905.0	1268.1
GBK035444	41.8	42.3	42.0	87.5	85.3	86.4	8.0	9.5	9.0	10.3	12.9	11.6	4.8	4.5	4.6	42.3	42.0	42.1	1567.5	952.5	1260.0
GBK022477	41.3	37.3	39.3	80.0	88.3	84.1	12.0	11.4	11.6	8.8	10.2	9.5	5.0	5.0	5.0	33.8	27.8	30.8	1488.8	1026.3	1257.5
NUA690	38.3	38.5	38.4	82.3	79.8	81.0	9.5	9.7	9.6	11.0	11.6	11.3	4.8	4.0	4.4	48.5	47.3	47.9	1786.3	710.0	1248.1
NUA730	33.0	34.0	33.5	76.0	75.8	75.9	10.0	7.7	8.4	9.5	8.5	9.0	4.5	3.8	4.1	47.5	44.3	45.9	1485.0	1000.0	1242.5
GBK035311	42.3	39.0	40.6	82.8	81.8	82.3	21.0	14.5	16.7	7.0	7.0	7.0	5.5	4.7	5.1	15.3	14.8	15.0	1463.8	1018.8	1241.3
GBK035026	41.3	39.5	40.4	87.3	82.0	84.6	11.5	14.7	13.6	9.8	9.3	9.5	5.0	3.8	4.4	23.3	24.0	23.6	1331.3	1140.0	1235.6
GBK035059	36.8	33.0	34.9	79.8	78.0	78.9	7.5	10.3	9.3	8.3	8.0	8.1	3.8	3.2	3.5	49.3	48.3	48.8	1635.0	833.8	1234.4
GBK035019	39.5	39.8	39.6	83.3	84.8	84.0	14.5	9.7	11.3	10.5	9.7	10.1	4.0	3.1	3.5	42.8	32.8	37.8	1843.8	618.8	1231.3
GBK035071	33.8	32.8	33.3	81.3	78.8	80.0	9.5	9.8	9.7	8.3	8.5	8.4	3.8	2.9	3.3	55.5	47.5	51.5	1457.5	1001.3	1229.4
NUA709	32.8	32.5	32.6	76.8	75.5	76.1	11.5	11.0	11.2	8.5	10.0	9.2	4.3	4.3	4.3	49.5	47.5	48.5	1142.5	1310.0	1226.3
GBK035330	44.8	38.3	41.5	89.3	79.8	84.5	21.5	10.5	14.2	10.3	10.5	10.4	5.5	5.3	5.4	20.3	36.3	28.3	1767.5	681.3	1224.4
GBK034981	43.8	33.0	38.4	93.8	88.8	91.3	14.5	15.0	14.8	8.3	9.4	8.8	6.0	4.8	5.4	16.8	18.3	17.5	1701.3	716.3	1208.8
GBK035338	37.0	36.0	36.5	77.5	72.8	75.1	15.0	21.4	19.3	9.3	9.4	9.3	5.0	5.1	5.0	20.0	17.5	18.8	1320.0	1086.3	1203.1
NUA 619	42.8	39.0	40.9	85.5	84.0	84.8	7.0	10.3	9.2	9.8	10.3	10.0	5.0	4.3	4.7	58.0	58.3	58.1	1238.8	1162.5	1200.6
GBK035067	33.0	32.8	32.9	76.8	79.5	78.1	10.5	11.4	11.1	8.5	8.4	8.4	4.0	3.1	3.5	50.3	46.8	48.5	1425.0	963.8	1194.4
GBK035356	39.8	36.3	38.0	81.8	83.0	82.4	12.0	9.0	10.0	10.5	9.9	10.2	6.0	5.1	5.5	26.8	27.8	27.3	1477.5	898.8	1188.1
GBK035081	32.8	32.3	32.5	76.3	77.3	76.8	7.0	13.8	11.6	7.5	9.1	8.3	4.3	3.9	4.1	49.5	44.0	46.8	1078.8	1291.3	1185.0
GBK035042	33.5	34.5	34.0	75.5	76.8	76.1	10.0	11.8	11.2	12.3	12.0	12.1	5.0	4.1	4.5	40.5	44.5	42.5	1211.3	1135.0	1173.1
GBK035047	32.8	32.5	32.6	76.5	78.5	77.5	7.5	9.3	8.7	8.8	8.9	8.8	4.0	3.5	3.8	52.3	45.1	48.7	1343.8	982.5	1163.1
GBK035286	33.8	34.5	34.1	74.0	78.3	76.1	14.5	13.3	13.7	8.8	8.0	8.4	5.0	3.5	4.3	30.0	27.5	28.8	1825.0	490.0	1157.5
GBK034995	32.8	33.8	33.3	75.3	79.3	77.3	6.5	8.4	7.8	8.5	8.8	8.6	4.3	3.3	3.8	47.0	44.5	45.8	1527.5	780.0	1153.8
KMT0113	38.0	34.3	36.1	81.3	80.3	80.8	9.0	9.1	9.1	8.3	8.3	8.3	4.0	3.3	3.7	48.5	45.0	46.8	1565.0	741.3	1153.1
GBK034987	43.0	40.8	41.9	86.5	83.8	85.1	11.0	14.2	13.5	8.5	8.8	8.7	6.0	5.8	5.9	17.8	17.8	17.8	1680.0	620.0	1150.0
GBK035359	38.5	37.3	37.9	85.8	88.5	87.1	21.5	14.3	16.7	8.5	8.4	8.4	5.0	3.8	4.4	23.0	28.0	25.5	1205.0	1092.5	1148.8
GBK035088	36.5	37.3	36.9	80.0	80.5	80.3	8.0	10.7	9.8	9.5	10.0	9.7	4.8	4.4	4.6	33.3	37.5	35.4	1526.3	757.5	1141.9
GBK035437	38.5	37.3	37.9	79.8	79.5	79.6	10.0	8.3	8.8	10.8	10.7	10.7	4.8	3.9	4.3	46.3	45.5	45.9	1350.0	932.5	1141.3
GBK035282	38.3	36.3	37.3	80.3	79.0	79.6	15.0	21.8	19.6	8.8	7.8	8.3	5.8	4.6	5.2	23.3	25.0	24.1	1380.0	885.0	1132.5
GBK035348	38.0	39.8	38.9	82.5	86.0	84.3	11.5	18.7	16.3	10.3	9.9	10.1	5.0	4.8	4.9	24.0	28.5	26.3	1057.5	1206.3	1131.9
GBK035305	35.0	37.0	36.0	77.3	78.8	78.0	10.5	11.8	11.4	8.5	8.6	8.6	5.3	3.3	4.3	37.8	33.5	35.6	1091.3	1145.0	1118.1
GBK035022	34.3	36.3	35.3	77.3	75.5	76.4	7.5	10.8	9.7	10.5	10.2	10.3	4.5	4.4	4.5	49.5	42.5	46.0	1605.0	621.3	1113.1
GBK035055	33.0	32.3	32.6	75.8	78.0	76.9	8.5	8.6	8.6	8.8	9.1	8.9	4.0	3.8	3.9	44.8	50.8	47.8	1310.0	908.8	1109.4
GBK047121	37.0	35.3	36.1	83.5	78.3	80.9	10.5	10.8	10.9	9.8	8.4	9.1	3.8	3.3	3.5	45.8	43.3	44.5	1083.8	1132.5	1108.1
GBK035012	40.3	40.5	40.4	82.3	84.3	83.3	13.5	8.9	10.4	10.0	10.1	10.0	4.5	3.6	4.0	44.5	40.3	42.4	1417.5	777.5	1097.5
NUA611	43.8	41.8	42.8	88.0	86.8	87.4	10.0	10.4	10.3	9.5	11.1	10.3	5.8	3.8	4.8	49.3	50.3	49.8	1255.0	937.5	1096.3
GBK035321	37.8	36.0	36.9	80.8	79.3	80.0	9.5	8.6	8.9	8.3	9.2	8.7	4.3	3.6	3.9	46.8	48.8	47.8	1465.0	710.0	1087.5
NUA604	38.8	36.8	37.8	83.0	84.0	83.5	8.5	13.6	11.9	8.3	9.1	8.7	3.5	4.0	3.8	45.5	44.0	44.8	898.8	1261.3	1080.0
GBK035394	39.3	38.3	38.8	78.5	70.0	74.3	17.0	10.3	12.6	8.0	8.7	8.4	5.0	4.5	4.8	17.5	18.8	18.1	1665.0	487.5	1076.3

Supplementary Table 1. Contd.

GBK035020	39.5	39.8	39.6	86.0	85.3	85.6	13.5	14.7	14.3	10.8	11.2	11.0	5.0	4.3	4.7	26.0	29.3	27.6	995.0	1152.5	1073.8
GBK035076	32.8	33.8	33.3	77.5	77.0	77.3	9.0	11.6	10.7	8.8	8.6	8.7	3.5	3.6	3.5	54.8	47.5	51.1	1363.8	783.8	1073.8
KMT0118	37.0	37.3	37.1	78.0	77.3	77.6	9.5	9.6	9.6	9.5	9.8	9.7	4.5	4.3	4.4	41.8	37.8	39.8	1417.5	701.3	1059.4
GBK034984	38.5	36.8	37.6	77.0	77.8	77.4	12.5	15.0	14.2	7.8	7.5	7.6	5.3	4.0	4.6	18.3	19.5	18.9	1233.8	857.5	1045.6
GBK034966	40.3	40.8	40.5	88.8	89.8	89.3	18.5	18.8	18.7	9.5	9.3	9.4	6.8	4.9	5.8	21.3	21.5	21.4	1218.8	868.8	1043.8
GBK035281	36.0	34.3	35.1	77.5	77.5	77.5	8.5	10.6	9.9	8.8	9.3	9.0	4.5	3.7	4.1	47.0	42.8	44.9	1415.0	665.0	1040.0
GBK035431	47.0	40.8	43.9	91.8	82.5	87.1	12.5	14.5	13.8	11.8	10.0	10.9	4.5	4.1	4.3	40.8	39.5	40.1	1328.8	738.8	1033.8
GBK035062	33.0	33.3	33.1	76.5	79.3	77.9	7.0	9.2	8.4	8.8	9.4	9.1	4.0	3.1	3.5	48.5	47.0	47.8	1305.0	750.0	1027.5
GBK035354	38.8	39.0	38.9	86.0	81.0	83.5	17.0	15.8	16.2	8.5	8.9	8.7	5.0	4.7	4.8	22.0	22.5	22.3	932.5	1120.0	1026.3
GBK035048	32.5	33.0	32.8	76.8	75.8	76.3	6.0	9.5	8.3	8.0	8.8	8.4	4.0	3.4	3.7	47.8	48.0	47.9	1157.5	882.5	1020.0
GBK035068	37.5	39.0	38.3	82.8	84.0	83.4	7.0	8.5	8.0	9.8	9.4	9.6	4.5	4.7	4.6	41.3	40.8	41.0	1222.5	811.3	1016.9
GBK035277	40.8	35.5	38.1	79.3	81.5	80.4	11.5	13.8	13.0	8.3	9.0	8.6	6.0	4.7	5.3	18.5	19.8	19.1	1272.5	757.5	1015.0
KNB0104	38.8	39.3	39.0	86.3	85.0	85.6	9.0	14.0	12.3	10.3	10.0	10.1	6.0	5.1	5.5	31.0	26.3	28.6	1452.5	561.3	1006.9
NUA686	37.3	36.5	36.9	82.8	81.0	81.9	10.0	11.4	10.9	9.3	8.9	9.1	4.3	3.9	4.1	41.8	39.3	40.5	1200.0	800.0	1000.0
GBK035020	36.8	38.3	37.5	82.8	82.8	82.8	11.5	13.0	12.5	10.5	10.6	10.5	5.5	5.7	5.6	21.5	23.8	22.6	857.5	1131.3	994.4
KMT0105	34.3	35.0	34.6	76.5	79.8	78.1	9.0	9.7	9.4	9.0	11.2	10.1	4.0	4.3	4.1	47.3	45.5	46.4	1293.8	693.8	993.8
GBK035078	35.5	32.3	33.9	75.0	76.5	75.8	6.5	11.0	9.5	7.8	8.5	8.1	4.0	3.3	3.6	48.8	43.8	46.3	1026.3	951.3	988.8
GBK035339	36.5	37.8	37.1	83.8	82.8	83.3	6.5	8.6	7.9	11.0	10.1	10.6	5.3	4.5	4.9	31.3	30.3	30.8	1422.5	552.5	987.5
GBK035042	35.5	35.8	35.6	79.3	79.3	79.3	15.5	14.2	14.6	11.0	8.3	9.6	5.5	3.8	4.6	38.0	35.3	36.6	1383.8	568.8	976.3
GBK034992	37.3	36.5	36.9	83.3	80.5	81.9	10.0	13.8	12.5	14.5	14.0	14.2	5.3	4.9	5.1	45.8	42.8	44.3	1055.0	888.8	971.9
GBK035039	34.0	34.5	34.3	82.8	82.5	82.6	10.0	8.9	9.3	9.8	9.7	9.7	4.0	3.9	4.0	48.5	41.0	44.8	1332.5	601.3	966.9
NUA636	33.5	32.5	33.0	75.8	76.3	76.0	7.0	8.4	7.9	9.3	9.8	9.5	4.0	3.7	3.8	49.3	45.8	47.5	953.8	975.0	964.4
GBK035341	38.3	36.3	37.3	82.5	79.8	81.1	15.0	13.7	14.1	9.8	9.3	9.5	5.5	4.6	5.0	24.3	23.0	23.6	1286.3	640.0	963.1
GBK035007	41.0	34.5	37.8	99.0	83.8	91.4	12.0	5.6	7.7	11.0	11.0	11.0	5.0	3.4	4.2	46.3	48.0	47.1	1343.8	547.5	945.6
NUA Ciankui	39.8	39.3	39.5	82.0	85.3	83.6	10.0	8.5	9.0	9.3	9.2	9.2	3.8	3.2	3.5	51.5	47.3	49.4	1250.0	628.8	939.4
GBK034965	38.8	38.0	38.4	81.3	83.8	82.5	10.0	7.7	8.4	14.3	13.2	13.7	6.0	3.8	4.9	41.8	36.0	38.9	1286.3	591.3	938.8
GBK034973	43.0	40.5	41.8	86.0	82.0	84.0	20.0	19.0	19.3	8.5	9.0	8.7	6.3	5.3	5.8	18.8	17.8	18.3	900.0	972.5	936.3
GBK035035	34.0	35.0	34.5	81.3	81.8	81.5	9.0	9.4	9.3	8.5	8.0	8.2	4.3	3.5	3.9	50.3	46.5	48.4	1186.3	680.0	933.1
GBK034977	37.0	38.5	37.8	83.5	84.5	84.0	9.5	9.9	9.8	10.5	10.1	10.3	5.5	3.3	4.4	52.0	49.8	50.9	1036.3	821.3	928.8
GBK035011	38.3	34.5	36.4	81.0	81.3	81.1	14.5	11.5	12.5	10.5	9.5	10.0	4.0	3.5	3.8	49.0	48.3	48.6	1463.8	350.0	906.9
GBK035024	42.5	41.3	41.9	85.3	89.0	87.1	10.0	9.7	9.8	11.8	11.5	11.6	5.3	3.8	4.5	46.8	49.0	47.9	1071.3	735.0	903.1
GBK035409	32.5	34.3	33.4	78.0	77.8	77.9	17.5	10.8	13.0	9.5	8.6	9.1	5.0	3.8	4.4	35.0	30.5	32.8	1341.3	463.8	902.5
GBK035323	36.0	35.5	35.8	78.3	78.0	78.1	6.5	15.3	12.3	9.5	8.8	9.2	5.0	4.0	4.5	36.3	29.5	32.9	1101.3	668.8	885.0
GBK035079	34.0	33.0	33.5	80.8	81.8	81.3	14.0	8.7	10.4	9.3	9.7	9.5	4.8	3.8	4.3	49.5	44.3	46.9	1042.5	693.8	868.1
GBK035440	34.8	35.3	35.0	74.8	77.5	76.1	12.5	10.6	11.2	10.8	10.4	10.6	5.5	4.3	4.9	34.8	31.3	33.0	937.5	788.8	863.1
GBK035030	42.3	36.5	39.4	83.0	76.0	79.5	12.5	14.8	14.1	11.5	9.9	10.7	5.0	4.4	4.7	35.8	28.5	32.1	833.8	891.3	862.5
GBK035409b	36.0	36.5	36.3	81.3	81.3	81.3	7.0	11.0	9.7	8.8	9.0	8.9	4.5	4.4	4.5	35.0	33.0	34.0	995.0	728.8	861.9
KMT0108	39.8	33.5	36.6	78.5	75.8	77.1	13.0	8.5	10.0	8.8	10.1	9.4	5.0	4.1	4.5	47.0	48.3	47.6	777.5	942.5	860.0
GBK035337	36.8	40.8	38.8	80.0	87.5	83.8	17.5	16.2	16.6	9.5	8.7	9.1	6.3	5.2	5.7	20.0	19.3	19.6	1235.0	482.5	858.8
NUA609	42.5	42.0	42.3	89.3	86.5	87.9	5.5	12.8	10.4	11.8	11.2	11.5	4.5	3.9	4.2	43.3	41.8	42.5	975.0	727.5	851.3
GBK035341	44.8	40.3	42.5	85.3	82.5	83.9	13.5	17.4	16.1	10.5	11.1	10.8	5.8	5.3	5.5	29.3	28.0	28.6	810.0	891.3	850.6

Supplementary Table 1. Contd.

NUA596	40.8	42.0	41.4	83.0	87.3	85.1	6.5	6.4	6.4	10.8	8.5	9.6	3.8	3.4	3.6	53.5	48.5	51.0	1315.0	381.3	848.1
GBK035331	38.3	36.0	37.1	80.8	78.3	79.5	8.0	6.8	7.2	11.5	12.3	11.9	4.5	4.3	4.4	51.3	51.0	51.1	1268.8	427.5	848.1
GBK035069	32.5	34.5	33.5	76.5	78.5	77.5	7.0	7.5	7.3	8.8	9.5	9.1	4.5	3.8	4.2	48.8	41.3	45.0	1233.8	461.3	847.5
GBK035420	41.8	44.0	42.9	83.5	88.0	85.8	20.0	14.5	16.3	8.0	8.2	8.1	4.8	4.8	4.8	20.8	17.5	19.1	1490.0	196.3	843.1
GBK035397	37.0	34.5	35.8	78.0	78.5	78.3	7.0	6.5	6.6	8.8	9.3	9.0	4.3	3.6	3.9	43.0	40.0	41.5	1043.8	640.0	841.9
GBK035065	44.0	40.3	42.1	88.8	86.3	87.5	11.0	6.2	7.8	9.3	17.3	13.3	5.0	4.4	4.7	42.3	39.3	40.8	1116.3	552.5	834.4
GBK035319	33.0	33.8	33.4	79.3	77.3	78.3	11.0	10.1	10.4	8.3	9.0	8.6	4.3	4.3	4.3	41.5	38.8	40.1	886.3	773.8	830.0
GBK035046	32.5	32.8	32.6	77.3	77.3	77.3	6.0	7.6	7.1	9.5	8.5	9.0	4.5	4.0	4.3	53.0	45.3	49.1	1166.3	486.3	826.3
GBK035379	45.5	36.5	41.0	85.3	88.5	86.9	17.5	16.1	16.6	9.5	7.7	8.6	5.5	4.5	5.0	16.8	17.5	17.1	948.8	685.0	816.9
GBK035068	33.5	32.8	33.1	76.8	80.3	78.5	7.0	8.3	7.8	8.5	8.7	8.6	5.3	3.6	4.4	49.3	46.3	47.8	818.8	788.8	803.8
GBK035334	40.5	42.3	41.4	87.0	88.5	87.8	21.0	18.1	19.1	7.5	8.5	8.0	5.8	4.6	5.2	20.8	20.5	20.6	928.8	673.8	801.3
GBK035066	41.8	40.3	41.0	78.5	80.0	79.3	12.0	10.1	10.7	8.8	9.0	8.9	5.3	4.0	4.6	30.5	31.3	30.9	1000.0	600.0	800.0
GBK034990	44.0	43.5	43.8	87.8	87.5	87.6	23.5	23.6	23.6	9.5	8.5	9.0	6.5	4.8	5.7	15.5	16.5	16.0	1273.8	313.8	793.8
GBK035054	33.0	33.0	33.0	78.3	78.0	78.1	8.0	5.9	6.6	9.8	8.0	8.9	4.0	3.1	3.5	51.8	43.3	47.5	1131.3	437.5	784.4
GBK034969	38.3	39.5	38.9	80.3	81.5	80.9	11.5	14.3	13.4	11.5	12.0	11.8	4.8	4.4	4.6	34.3	37.3	35.8	911.3	653.8	782.5
GBK035330	34.0	33.8	33.9	79.3	78.0	78.6	11.5	8.7	9.6	10.0	10.0	10.0	5.3	5.5	5.4	42.5	37.5	40.0	878.8	682.5	780.6
GBK035413	38.5	37.3	37.9	79.3	78.5	78.9	21.0	15.3	17.2	7.5	7.2	7.3	5.3	3.8	4.5	18.8	19.5	19.1	1118.8	431.3	775.0
GBK035324	42.0	40.8	41.4	83.5	83.8	83.6	12.5	22.2	18.9	8.3	8.1	8.2	4.8	4.8	4.8	27.8	21.0	24.4	1046.3	487.5	766.9
GBK035294	35.8	34.8	35.3	81.5	81.8	81.6	6.0	6.1	6.1	10.8	10.1	10.4	5.5	4.5	5.0	40.0	43.0	41.5	856.3	661.3	758.8
GBK035314	42.3	36.0	39.1	86.5	84.5	85.5	21.5	15.8	17.7	9.0	8.7	8.8	5.5	4.3	4.9	18.5	21.0	19.8	1322.5	195.0	758.8
GBK034984	39.8	42.5	41.1	83.8	84.0	83.9	12.0	18.6	16.4	7.5	7.8	7.7	6.5	5.0	5.8	17.0	17.0	17.0	1107.5	363.8	735.6
GBK035356	42.0	40.0	41.0	82.5	86.0	84.3	15.5	9.7	11.6	8.0	8.9	8.4	4.8	4.0	4.4	21.3	18.5	19.9	1251.3	216.3	733.8
GBK035362	47.3	43.0	45.1	89.8	86.8	88.3	14.0	16.2	15.4	8.5	9.2	8.8	5.5	4.5	5.0	20.5	19.8	20.1	640.0	807.5	723.8
GBK035395 a	37.5	36.8	37.1	82.0	84.8	83.4	14.5	14.0	14.2	9.3	7.9	8.6	5.3	3.8	4.5	20.0	20.3	20.1	1110.0	316.3	713.1
GBK035355	38.5	38.0	38.3	82.5	83.0	82.8	23.5	16.4	18.8	7.8	7.8	7.8	5.0	4.5	4.8	21.0	22.3	21.6	1101.3	303.8	702.5
GBK035408	36.5	37.3	36.9	84.3	87.8	86.0	9.0	7.7	8.1	10.0	10.3	10.1	3.8	3.7	3.7	50.3	44.8	47.5	1081.3	318.8	700.0
GBK035419	46.0	37.3	41.6	87.0	86.0	86.5	13.5	12.3	12.7	9.3	9.3	9.3	6.3	5.0	5.6	19.0	18.8	18.9	617.5	763.8	690.6
GBK035322	34.8	35.3	35.0	74.8	73.8	74.3	12.0	12.2	12.1	8.3	10.4	9.3	4.8	4.6	4.7	33.5	29.0	31.3	616.3	757.5	686.9
GBK035313	43.5	42.3	42.9	84.8	84.0	84.4	20.0	25.1	23.4	8.3	7.7	8.0	6.3	4.7	5.5	17.8	15.5	16.6	732.5	628.8	680.6
GBK035438	45.5	39.8	42.6	88.8	84.0	86.4	7.5	9.9	9.1	10.3	10.0	10.1	4.5	4.3	4.4	27.8	41.8	34.8	767.5	563.8	665.6
GBK035408	37.5	35.8	36.6	81.3	76.3	78.8	9.0	15.3	13.2	11.0	12.8	11.9	5.8	5.3	5.5	34.3	29.0	31.6	848.8	470.0	659.4
GBK035291	41.0	39.8	40.4	85.3	85.3	85.3	10.0	11.8	11.2	9.5	11.0	10.3	4.3	4.5	4.4	32.3	33.8	33.0	677.5	620.0	648.8
GBK035402	37.0	38.0	37.5	82.3	84.0	83.1	15.0	4.1	7.7	12.3	9.9	11.1	5.5	3.7	4.6	35.0	32.5	33.8	1051.3	237.5	644.4
GBK035410	39.8	38.8	39.3	83.0	79.0	81.0	24.0	14.9	17.9	8.3	7.7	8.0	5.0	3.8	4.4	24.3	18.5	21.4	968.8	306.3	637.5
GBK035391	42.3	39.3	40.8	85.0	81.8	83.4	17.0	17.0	17.0	8.3	7.5	7.9	5.0	3.5	4.3	21.3	24.0	22.6	681.3	576.3	628.8
GBK035315	41.8	41.0	41.4	85.5	81.3	83.4	15.5	17.0	16.5	8.5	7.6	8.1	5.8	4.8	5.3	16.8	16.5	16.6	856.3	378.8	617.5
GBK034968	37.8	38.3	38.0	81.0	81.0	81.0	13.0	9.3	10.5	10.3	11.0	10.6	5.3	4.5	4.9	36.8	33.0	34.9	930.0	300.0	615.0
GBK034965	44.0	35.3	39.6	87.0	86.3	86.6	11.5	8.4	9.4	8.3	8.2	8.2	5.3	5.0	5.1	18.5	15.0	16.8	933.8	272.5	603.1
GBK035353	42.3	40.0	41.1	85.3	87.8	86.5	20.5	15.5	17.2	8.3	7.2	7.7	4.8	3.8	4.3	20.5	22.5	21.5	875.0	308.8	591.9
GBK035346	39.8	36.5	38.1	81.0	83.8	82.4	12.0	11.8	11.9	10.5	11.1	10.8	4.5	4.9	4.7	27.5	24.8	26.1	677.5	502.5	590.0
GBK034975	41.3	40.8	41.0	85.0	84.3	84.6	14.5	13.6	13.9	10.0	8.6	9.3	5.3	5.0	5.1	20.0	22.8	21.4	512.5	650.0	581.3

Supplementary Table 1. Contd.

GBK035060	43.5	39.8	41.6	89.5	82.5	86.0	8.0	6.3	6.8	9.0	9.4	9.2	4.5	4.1	4.3	39.8	40.3	40.0	557.5	598.8	578.1
GBK035377	43.5	38.5	41.0	91.0	89.3	90.1	10.5	12.3	11.7	11.3	10.1	10.7	6.3	4.5	5.4	25.0	26.0	25.5	601.3	522.5	561.9
GBK035364	41.8	39.8	40.8	84.0	83.5	83.8	15.0	11.7	12.8	9.3	9.0	9.1	5.3	4.0	4.6	23.0	23.5	23.3	743.8	365.0	554.4
GBK035304b	37.8	37.8	37.8	88.0	83.3	85.6	6.5	7.2	6.9	10.3	8.7	9.5	5.3	4.3	4.8	24.5	24.0	24.3	755.0	326.3	540.6
GBK035318	33.8	33.8	33.8	75.8	75.0	75.4	8.5	12.1	10.9	10.5	10.4	10.5	4.5	3.8	4.1	47.0	44.3	45.6	740.0	338.8	539.4
GBK035049	36.3	33.0	34.6	74.8	79.0	76.9	10.0	8.3	8.8	7.5	8.9	8.2	3.8	3.5	3.6	41.3	39.5	40.4	595.0	435.0	515.0
GBK035340	37.0	42.3	39.6	81.8	80.3	81.0	8.5	5.5	8.6	9.6	9.2	9.4	5.8	5.1	5.4	22.3	21.8	22.0	547.5	481.3	514.4
GBK035360	38.3	38.8	38.5	81.5	84.5	83.0	15.5	17.3	16.7	7.8	8.2	8.0	5.0	3.9	4.5	19.3	22.0	20.6	693.8	332.5	513.1
GBK035034	37.8	36.0	36.9	76.5	84.0	80.3	27.5	20.7	22.9	7.0	9.0	8.0	4.5	4.3	4.4	17.5	20.0	18.8	478.8	453.8	466.3
GBK034987	43.0	38.5	40.8	85.3	87.8	86.5	15.0	17.5	16.7	9.5	9.2	9.3	6.3	4.4	5.3	19.5	19.0	19.3	250.0	583.8	416.9
GBK034995	34.3	33.0	33.6	77.8	80.3	79.0	9.5	12.7	10.9	11.8	9.8	10.8	5.3	3.8	4.5	36.5	23.5	30.0	558.8	205.0	381.9
GBK035431	40.8	37.5	39.1	86.5	82.8	84.6	18.5	15.7	16.6	8.5	8.6	8.6	5.0	5.2	5.1	21.0	22.3	21.6	408.8	332.5	370.6
GBK035023	45.3	41.3	43.3	90.5	86.8	88.6	10.0	3.8	5.9	12.5	10.9	11.7	4.5	3.3	3.9	54.0	46.3	50.1	576.3	75.0	325.6
GBK035295	38.0	37.8	37.9	82.3	82.0	82.1	15.5	13.3	14.1	9.8	8.7	9.2	6.5	4.3	5.4	21.8	19.0	20.4	350.0	227.5	288.8
GBK035320	40.3	38.5	39.4	72.5	83.5	78.0	10.0	8.3	8.8	9.3	8.6	8.9	5.0	3.9	4.5	21.3	21.5	21.4	300.0	200.0	250.0
GBK035350	37.0	37.0	37.0	81.3	87.8	84.5	15.0	14.5	14.7	7.3	6.6	6.9	4.3	3.8	4.0	20.8	19.3	20.0	248.8	192.5	220.6
Mean	**38.4**	**37.3**	**37.8**	**82.3**	**81.6**	**82.0**	**12.3**	**12.8**	**12.6**	**9.9**	**9.9**	**9.9**	**4.9**	**4.3**	**4.6**	**37.6**	**36.2**	**36.9**	**1528.5**	**1005.4**	**1267.0**
LSD accessions (A)		1.9**			3.4**			5.1**			1.4**			0.7**			4.4**			322.5**	
LSD seasons (S)		0.2**			0.4**			0.6**			0.2**			0.1**			0.5**			65.2**	
LSD A*S		S**			S**			S**			S**			S**			S**			S**	
CV%		5.2			4.2			35.5			14.0			16.5			12.1			32.3	

LR=Long rains, SR= Short rains, CV= coefficient of variation.