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# Evaluating natural infection of fungal, bacterial and viral pathogens to dry bean genotypes under field conditions

**Papias H. Binagwa[1,2*], Guohao He[2], Marceline Egnin[2], Gregory C. Bernard[2], Desmond Mortley[2] and Conrad K. Bonsi[2]**

[1]Integrative Bioscience (IBS), Ph.D. Program, Tuskegee University, AL 36088, USA.
[2]Department of Agricultural and Environmental Sciences, Tuskegee University, AL 36088, USA.

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**Fungal, bacterial and viral diseases are economic foliar diseases that cause yield losses, between 40 and 100%, in commonly grown dry bean cultivars in the world. Development of disease resistance genotypes is a complex interaction between genetic and environmental factors. This study focused on determining the natural infection of disease-causing pathogens of angular leaf spot, powdery mildew, bacterial blight and bean common mosaic virus in different agro-ecologies in relation to grain yield. Diversity of 211 bean genotypes were tested at two different disease hot spots areas under incomplete block design, with two replications for two cropping seasons in Tanzania. Diseases severity was significantly different ($p<0.001$) for genotypes and their interactions with the environment and season. Higher disease severity was observed at Lyamungo site than Selian site. Effects of genotypes by environment were observed with maximum yield of 2170 kg/ha to low yield of 398 kg/ha with the grand mean of 1151.54 kg/ha. High annual rainfall and relative humidity contributed to disease development among the tested environment. Five genotypes (FEB 189, A774, NUA 16, KG 71-4 and DOR 766) expressed trait of resistance to above diseases and are advised to be incorporated in breeding programs for enhancing dry bean productivity.**

**Key words:** Diseases, losses, productivity, G*E interaction.

## INTRODUCTION

Dry bean (*Phaseolus vulgaris* L.) is the most widely grown and significantly consumed grain legume in the world (Broughton et al., 2003; FAOSTAT, 2018). There are two origin centers, Mesoamerican origin in southern Mexico and Guatemala, as well as Andean origin in Peru and Columbia (Landon, 2008; Kwak et al., 2009) where this crop originated from; before spreading across the world (Kwak and Gepts, 2009). Dry bean is the primary food crop with the highest level of variation in adaptation, maturity, growth habit (habitat) and seed characteristics (size, shape and color) (Peters, 1993). Additionally, some geographic regions are favored with producing large size seeds, medium (25 to 40 g per 100 seeds) or large (>40 g per 100 seeds).

Global production is hindered by biotic and abiotic factors resulting in commercial varieties yielding lower

*Corresponding author. E-mail: pbinagwa8224@tuskegee.edu. Tel: +255764951596.

than their potentiality (De Leque and Creamer, 2014). Based on the economic importance, fungal diseases cause higher losses followed by bacterial and viral diseases (Mahuku and Riascos, 2004). For instance, the percentage of damage caused by fungal diseases is 80% by Angular Leaf Spot (ALS), *Phaeoisariopsis griseola* (Sacc.); 100% by Anthracnose, *Colletotrichum lindemuthianum;* and more than 50% by Powdery mildew (PM), *Erysipelas polygoni*. Bean common blight (*Xanthomonas axonopodis* pv. *phaseoli),* which is a bacterial disease, causes 45% losses (Nkalubo et al., 2007). Viral diseases, such as *Bean common mosaic virus* (BCMV) and *Bean common mosaic necrosis virus* (BCMNV), can cause 100% yield losses (Hillocks et al., 2006; Buruchara et al., 2010; Singh and Schwartz, 2010; Mwaipopo et al., 2016) with their major transmission and survival structures which includes seeds, wind and plant debris.

These diseases (ALS, CBB, PM and BCMV) severely affect farmers' field in Tanzania, which ranks number one in Africa and 6th in the world (FAOSTAT, 2018). The development of foliar disease resistance bean genotypes through understanding of the environmental factors and gene alleles interactions may help gain insight into disease etiology and sub-classification; also, management options would offer better strategies for bean breeding program (Wang et al., 2005). The marked recent improvement in bean breeding program is in the initial stage for biotechnology approaches (Harwell et al., 2011). It has been shown that field crop phenotyping under natural infection assists desirable trait assessments for genetic variability aimed at selecting genotypes with better traits for enhanced improvement (Sankaran et al., 2015). The objectives of this research study are to (a) evaluate the response of dry bean genotypes to ALS, CBB, PM and BCMV diseases at different environments and seasons; (b) screen best genotypes with high yield and resistance traits for breeding purposes to all diseases and their specificity; (c) compare disease occurrence in relation to cropping seasons for actual rainfall and temperature.

## MATERIALS AND METHODS

### Plant materials

A total of 211 genotypes were collected from different sources: Ethiopia (12), International Center for Tropical Agriculture (CIAT)-Kawanda (184), Kenya (10), Tanzania (3) and Rwanda (2) (Supplement 1) with various market classes evaluated under natural field conditions for 2016/17 and 2017/18 cropping season. From these materials, resistant checks of MEX 54 and G5686 (Mahuku et al., 2009) was used for ALS, Vax 1(Singh et al., 2001) was used for CBB, MAZ 47 was used for BCMV; unfortunately, checks for PM disease was not included.

### Experimental area

The experiment was conducted at low to high altitudes, 1407 m above sea level of S03°21.690' and E36°37.879' at Selian Agricultural Research Institute (SARI) and Tanzania Coffee Research Institute commonly called Lyamungo, with 992 m.a.s.l of 03°19.905' and E037°14.067', respectively. The characteristics of this soil area are: Eutrophic Brown Soils on volcanic and Alluvial sediments - Medium texture (loamy soils) (Brady and Weil, 2002; Landon, 1991). The soil contains organic carbon (0.53%), organic matter (0.92%), total nitrogen (0.079%), exchangeable potassium (0.17 cmol (+)/kg) and medium available phosphorous (8.0 mg/kg); this means that the soil fertility status is medium fertility which is moderately suitable for bean cultivation (Kiriba et al., 2020). These selected sites are close to the weather station, from whence respective weather data were collected.

### Disease evaluation and grain yield determination

Each disease (ALS, PM, CBB and BCMV) was rated using 1 to 9 scale as described by CIAT (1987) and CIAT-Kawanda (2013); where 1 to 3 refer to resistant, 4 to 6 intermediate, and 7 to 9 susceptible. Grain yield was measured from each plot using digital scale with 11lb (model No. SKS - 006, China). Final grain yield was extrapolated into kg/ha, using the following formula:
Grain yield (kg/ha) =$(dy * 10)/dx$

Where $dy$ =plot weight and $dx$=plot area.

### Experimental design

In both locations, in all growing season, trials were laid out under incomplete block design with two replications. The experimental plot size was 4 rows, 3.2 m long and 50 cm apart and 20 cm within a row. The harvested net plot size was 3.2 $m^2$ of the centered two rows of each plot. Other practices were carried out as recommended by National *Phaseolus* Bean Research Program in Tanzania (Binagwa, 2017).

### Statistical analysis

The collected data were subjected to GenStat 16th Edition with the following linear model:

$Yijk = \mu + Gi + \gamma j + Gi*\gamma j + \partial k + Gi*\gamma j* \partial k + eijk$

Where Yijk = Response variable (Yield) for variety i, environment j and season k; μ = Overall mean for all the observed response; Gi = Fixed effect of variety; γj = random environmental effect of the observed response; Gi*γj = Interaction effects between variety and environment; ∂k = Random effect of replication within a season; Gi*γj*∂k = Interaction effect of variety, environment and season; eijk = Random term error which is assumed to be normally distributed with 0 mean and variance $\delta^2$ which were summarized in a given results. Data were tested using Analysis of Variance (ANOVA) for single and multiple treatment interactions. The protected Least Significant Differences (LSD) of ($p$=0.05) were used to test for treatment comparison (Clewer and Scarisbrick, 2001; Yu 2008).

## RESULTS

### Classification of dry bean genotypes used

Through seed morphological description process, the

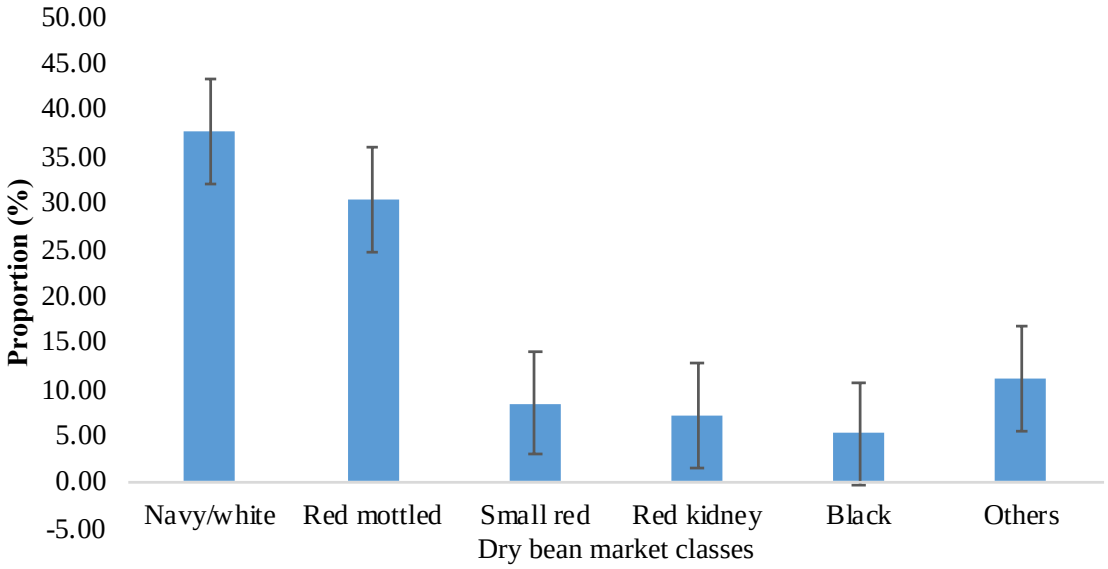


**Figure 1.** Proportional of dry bean seed market classes.

genotypes utilized were classified as 63.50% from Mesoamerican and 36.50% from Andean gene pools of origin. Based on market class, navy/white is dominant by 32.70% followed by red mottled, 30.33%. The remaining market classes were small red (8.53%), red kidney (7.10%), black, carioca, kablanket and cream (Figure 1). Seed size was large, medium and small, proportional to 36.02, 9.95 and 54.03%, respectively.

## Effects of fungal disease-causing pathogens

The ANOVA analysis showed that the effects of genotype, environment, season and the interactions of genotype and environment (G*E) were significantly different at p<0.001; while that of genotype and seasons where significant at p=0.002 for ALS infections. The effects of ALS disease caused by *P. griseola* were high at Lyamungo site with the severity of up to 5.00 scale; while 4.20 at SARI. The G*E effects were observed between the range of 2.00 to 3.50 scale (Figure 2A). In relation to season, infection was high in the 2017/18 season ALS, with severity score >5.00; while that of 2016/17 reached ~2.80 and most of the genotypes expressed none pathogen infection (Figure 2B). Overall, 38 genotypes had higher severity scores above the grand mean (Supplement 2). For PM infection caused by *E. polygoni*, disease severity was high at Lyamungo site with score >6.00; while ~4.50 at SARI (Figure 2C and D). The effects of genotypes, environment, season, G*E, G*S and G*E*S were also significant (p<0.001) for PM infection. The PM infection was high at Lyamungo, followed bywith SARI site during the 2017/2018 growing season, with severity scores between 2.00 to 7.00 and 1.00 to 5 .00 (Figure 2E) (Supplement 2).

## Effect of bean bacterial blight pathogen

Two bean growing season results showed significant difference (p<0.001) between genotype, season, G*E, G*S and G*E*S for CBB reaction, and about 82 genotypes showed their disease severity scores were above the grand mean of >3.00 scores. The effect was high at Lyamungo, ~4.70; while at SARI, severity scores was high up to 4.20 (Figure 2F). The growing season of 2017/2018 had more infections of CBB than that of 2016/2017 growing season, with more scatter points above 3.50 disease scores (Figure 3A and Supplement 2).

## Infection of bean common mosaic virus

There was significant difference (p<0.001) between G*E and G*E*S (p=0.03) for dry bean common mosaic virus. A few genotypes, namely CC 906, 222/1, Flor De Mayo, DOR 755, MLB48-89A and A 686, had severity scores within the ranges of 3.25 to 4.50. Narrow variation observed showed resistance scores across the tested sites due to most genotypes (Figure 3B and Supplement 2).

## Grain yield production across the environment and season

Genotype, environment, G*E and G*E*S showed

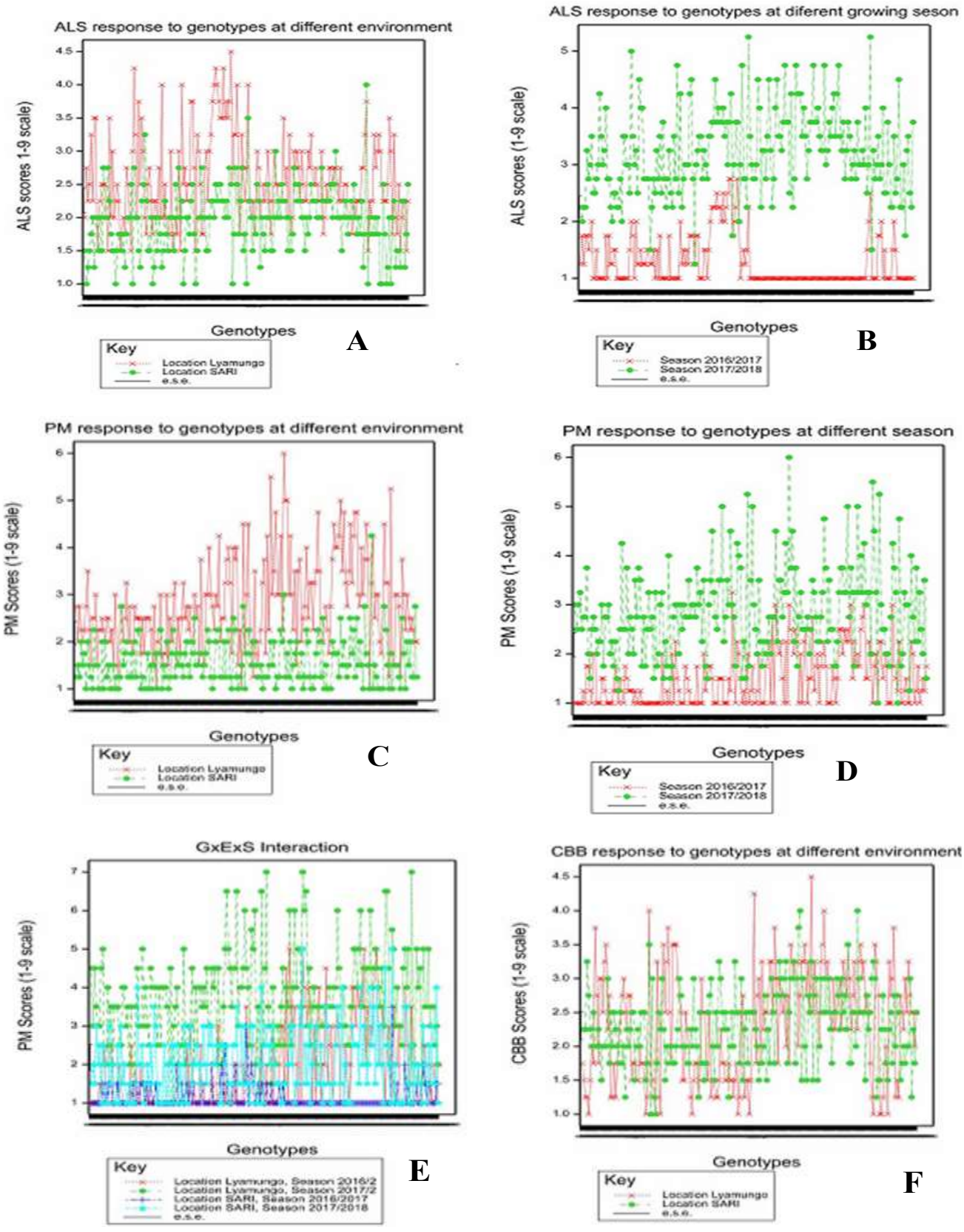


**Figure 2.** Response of disease to dry bean genotypes (A) genotype and environment interaction for ALS; (B) Genotype and season interaction for ALS; (C) Genotype and environment interaction for PM; (D) Genotype and season interaction for PM; (E) Genotype, environment and season interaction for PM; (F) Genotype and environment interaction for CBB.

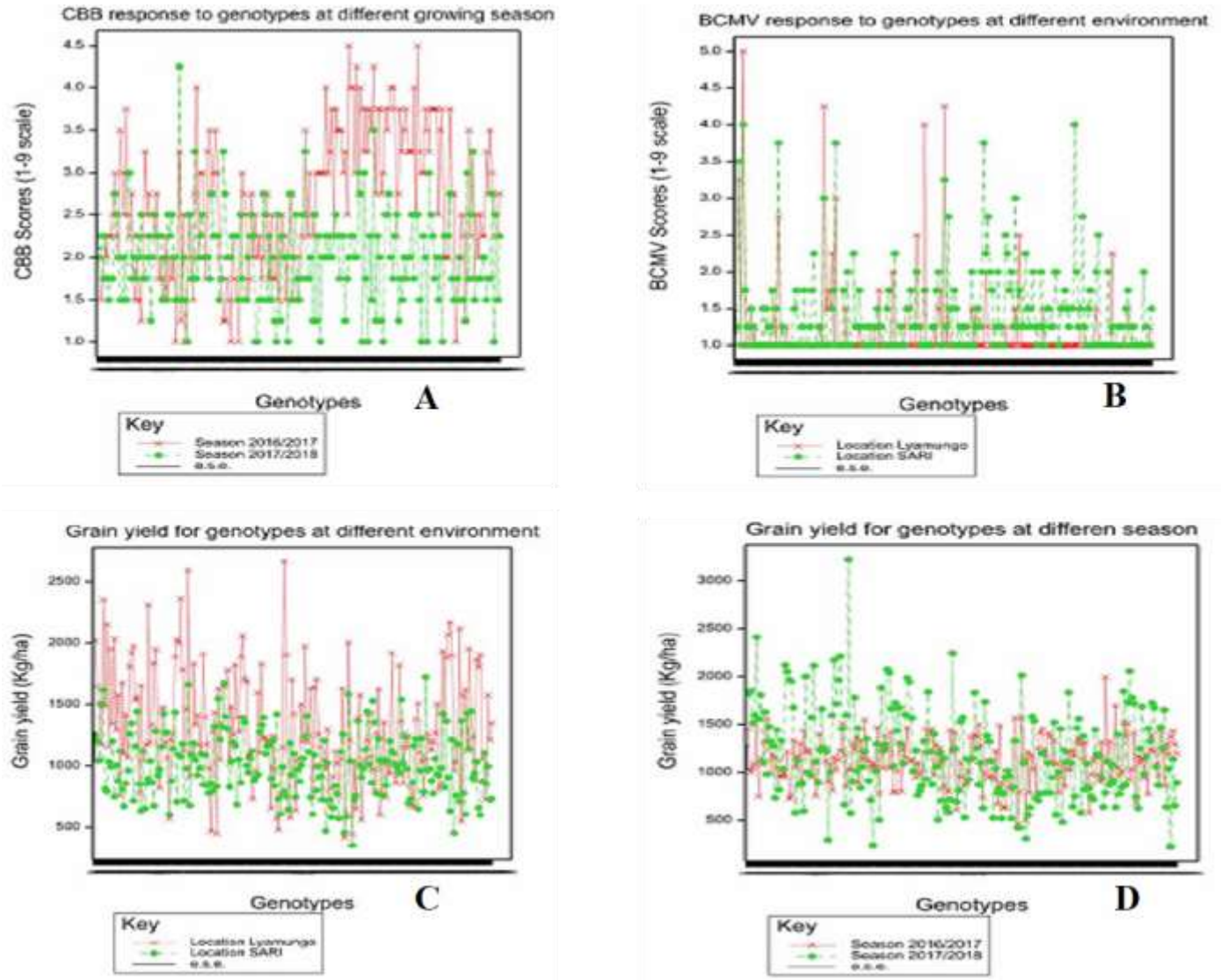


**Figure 3.** Response of disease to dry bean genotypes and grain yield; (A) Genotype and season interaction for CBB; (B) Genotype and environment interaction for BCMV; (C) Genotype and environment interaction for grain yield; (D) Genotype and season interaction for grain yield.

significant difference (<0.001) in season (p=0.004). Grain yield of all genotypes at the Lyamungo site was higher than that of SARI site across the testing seasons. For instance, maximum yield at Lyamungo was >2500 kg/ha; while the highest yield at SARI was ~1800 kg/ha and the lowest yield <500 kg/ha, with the grand mean of 1151.54 kg/ha for both locations (Figure 3C). The 2017/2018 growing season resulted in higher yield of >3000kg/ha; while that of 2016/2017 gave rise to approximately 2100 kg/ha (Figure 3D). Generally, Lyamungo site during 2017/2018 season performed better in this study and the best top five bean genotypes, FEB 189, A774, NUA 16, KG 71-4 and DOR 766, produced yield of 2127, 1982, 1793, 1725 and 1715 kg/ha, respectively (Figure 2C and D and Supplement 2).

**Climate and diseases occurrence during this study period**

Annual rainfall (mm), maximum temperature (°C) and mean temperature for consecutive four cropping seasons (2015-2018) were collected as well as annual relative humidity (%) for two cropping seasons (2017-2018). High annual rainfall was observed at Lyamungo site than that of SARI, across the cropping seasons. For instance, in 2018, annual rainfall was 2156.40 mm at Lyamungo but 1169.20 at SARI (Figure 4A). Mean and maximum temperature was higher at SARI compared to Lyamungo (Figure 4B and C); while relative humidity was reverse to temperature (Figure 4D). The negative correlation in both sites indicated that the higher the rainfall, the lower the

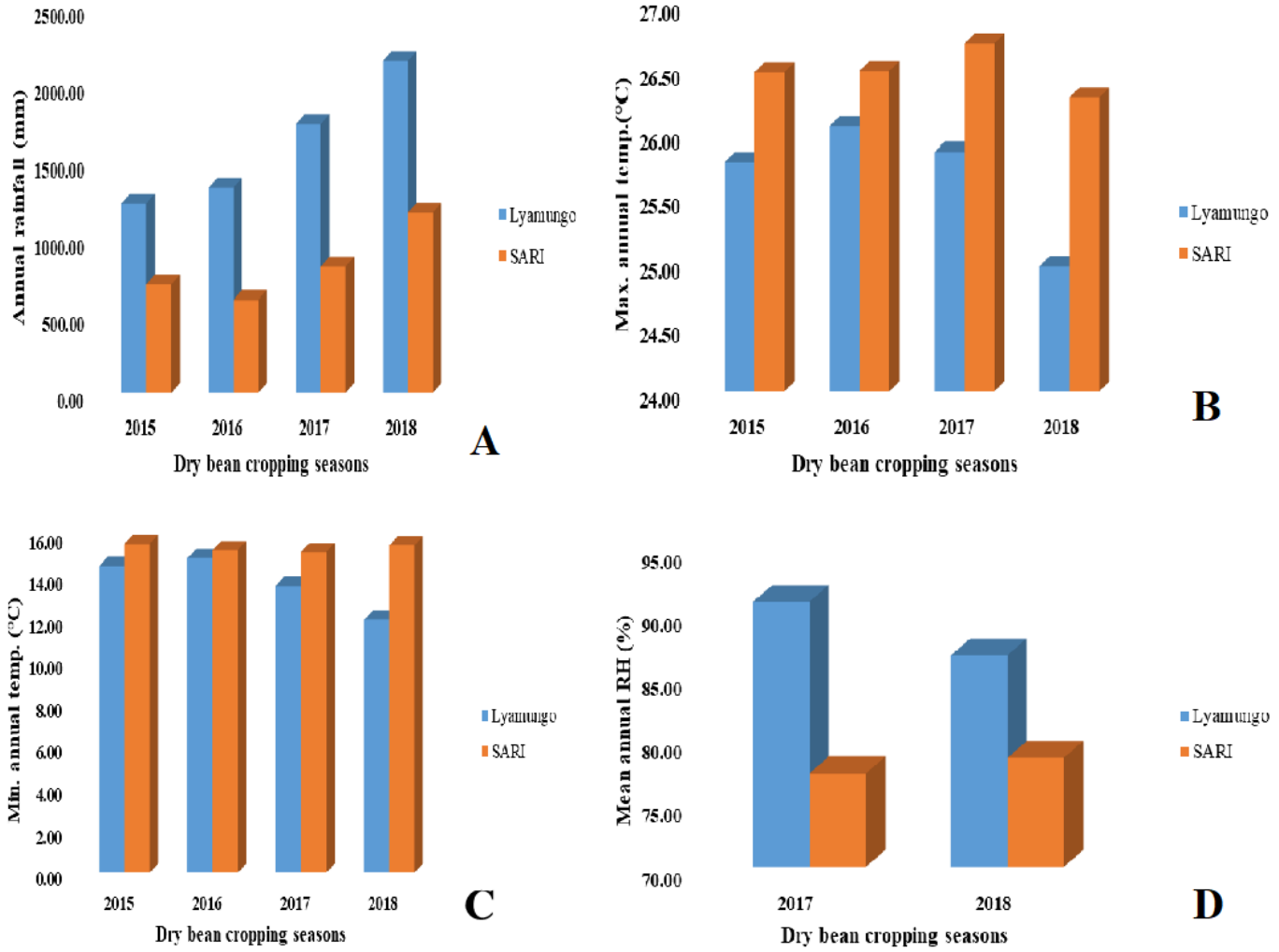


**Figure 4.** Annual climate statistics for experimental sites; (A) Annual rainfall, (B) Maximum average annual temperature; (C) Minimum average annual temperature; (D) Mean annual relative humidity.

temperature and the higher the relative humidity in these cropping seasons. Through comparative analysis, the high rainfall and relative humidity resulted in high severity of fungal, bacterial and viral diseases at Lyamungo; while at SARI, though disease severity was lower, productivity was also low, which may be attributed to terminal drought and abortion of flowers due to high temperature.

### Dry bean market class variations with respect to diseases effects and grain yield

Small red genotypes dominated the higher grain yield (>1500 kg/ha) compared to all accessions; while navy and red mottled genotypes produced yield range between 1000 and 1490 kg/ha. Red mottled genotypes with large to medium size were more susceptible to ALS, CBB and PM, with lower yield compared to other market classes. Small seeded genotypes, especially black, red and khaki striped such as A 686, MLB 48-89A, DOR 755, FLOR DE MAYO, 222/1 and CC 906, were more susceptible to BCMV disease and their yield was lower (Supplement 2). Although some genotypes were not infected by pathogens, their yields were lower (<1000 kg/ha), which may be due to poor germination and adaptability (Table 1). From the combined analysis that expressed the effects of GxE across the two bean growing seasons, ten resistant genotypes were identified for each diseases and were listed in Table 1. From this identification, small white and small red expressed trait of resistance under this field conditions than other market classes.

## DISCUSSION

The responses of genotypes to diseases through genotype and environmental interactions led to yield variations. Infection caused by ALS disease-causing

**Table 1.** Identified top 10 genotypes with trait of resistance per specific disease, market type, severity and grain yield.

| Economic disease | Genotypes | Market type | Score (1-9) | Yield (kg/ha) |
|---|---|---|---|---|
| Angular Leaf Spot (ALS) | KG 30-29 | White | 1.00 | 1257.00 |
| | Ranjonomby | White | 1.00 | 1679.00 |
| | DOR 755 | Small red | 1.00 | 1545.00 |
| | ZABR 16575-51F22 | White | 1.00 | 962.00 |
| | CN Bunsi (64) | White | 2.00 | 897.00 |
| | CC814 | Carioca | 2.00 | 1345.00 |
| | CN Bunsi (60) | White | 2.00 | 815.00 |
| | CN Bunsi (62) | White | 2.00 | 1145.00 |
| | G 31 | White | 2.00 | 1169.00 |
| | G 78 | White | 2.00 | 1239.00 |
| Powdery mildew (PM) | PAN 72 | White | 1.00 | 1219.00 |
| | CN Bunsi (64) | White | 1.00 | 897.00 |
| | SM 133 | White | 1.00 | 1412.00 |
| | ZABR 16573-78F22 | White | 1.00 | 1070.00 |
| | F1Population | White | 1.00 | 916.00 |
| | G 30 | White | 1.00 | 1190.00 |
| | G 60 | White | 1.00 | 1378.00 |
| | MEX 54 | Cream | 1.00 | 1725.00 |
| | MICHETTE | White | 1.00 | 645.00 |
| | Awash-1 | White | 1.00 | 1270.00 |
| Common Bacterial Blight (CBB) | DOR 771 | Small red | 1.00 | 1481.00 |
| | DOR 662 | Carioca | 1.00 | 1042.00 |
| | DOR 766 | Small red | 1.00 | 1715.00 |
| | KG 4-20 | Small red | 1.00 | 1223.00 |
| | RRN 47 | Small red | 1.00 | 1485.00 |
| | Selian 05 | Khaki | 1.00 | 1171.00 |
| | DOR 711 | Small red | 1.00 | 1368.00 |
| | MAZ 41 | Medium red | 2.00 | 927.00 |
| | DOR 708 | Red kidney | 2.00 | 1199.00 |
| | KG 114-185 | Small red | 2.00 | 1542.00 |
| Bean Common Mosaic Virus (BCMV) | 296/6 | Carioca | 1.00 | 1278.00 |
| | ALS 3 | Black | 1.00 | 1472.00 |
| | BAT 332 | Cream | 1.00 | 1391.00 |
| | C.2014/Hu/11 | White | 1.00 | 1149.00 |
| | C.2017/Hu/11 | White | 1.00 | 1224.00 |
| | C.2019/Hu/11 | White | 1.00 | 1244.00 |
| | CANPSULA | White | 1.00 | 1014.00 |
| | CIM 9313-1 | Khaki | 1.00 | 1500.00 |
| | CN Bunsi (62) | White | 1.00 | 1145.00 |
| | CN Bunsi (64) | White | 1.00 | 897.00 |

pathogen was observed during this study. Extreme rainfall and relative humidity in the field created an environment for diseases occurrence. Each bean genotype responded differently to pathogen infection in different environments, though phenotypic expression was strongly influenced by this pathogen. Some reports also stated that this pathogen caused serious infection because of high level of moisture in dry bean production areas, such as excess moisture in the field in Kenya (Mwang`ombe et al., 2007) and great lake regions in Tanzania, Uganda and Ethiopia (Pastor-Corrales et al., 1998; Nkalubo et al., 2007). Some genotypes which

tolerated excess moisture identified in this study could be selected for production in these specific areas. Also, other effects of ALS to yield loss in dry bean genotypes was observed in a three-year field experiment conducted by Jesus et al. (2001) in the 1997 and 1999 experiments, whereby ALS reached higher disease levels than rust under rust and ALS inoculations pathogens. Same results were gotten by Cichy et al. (2015), Liebenberg et al. (1997) on Andean diversity study, which was attributed to G*E and inappropriate good agricultural practices.

Powdery mildew severity was less considered as economic disease in Tanzania, but these experiments showed its economic impact, in that those plants attacked failed to produce even a single seed. The infection was high, up to 6.00 severity scores at Lyamungo site for most large seeded genotypes including NUA 137, NUA 145, NUA 15, SWAP 09 and NUA 244 which leads to poor grain yield of 1016.87, 758.28, 1056.09, 549.89 and 857.27kg/ha, respectively. Same infection was caused by *E. polygoni* pathogen of PM causes extensive damage with significant losses of up to 69% in Columbia, US; the infection occurred during flowering time (Steadman et al., 2005) and other losses of about 40 to 50% at Mexico's farmers' field. Effects of CBB range from leaves, pods to seeds and that's why it is regarded as seed borne disease (Lopez et al., 2006). The effects occurred both in the field through natural infection, which occurs under normal environmental conditions, and in greenhouse through inoculation procedures. High severity occurs under high rainfall and relative humidity as well as warm temperature conditions, between 25 and 35°C (Chaube et al., 1992). However, in the green house, high relative humidity does not influence the CBB, causing organisms to infect plants like that under field conditions (Akhavan et al., 2009).

This study shows the environmental condition for the diseases to occur across the tested locations. *Bean common mosaic virus* showed less variation in its occurrence in the testing sites, while few genotypes were affected by this virus. Despite not expressing its economic importance, but for those few genotypes affected, it really hit across the tested environments. The losses caused by BCMV and BCMNV impacted severely not only on commercial scale cultivation of this high-value crop but also on production by smallholder farmers in the developing world, where bean serves as a key source of dietary protein and mineral nutrition (Worrall et al., 2015). The tested resource materials in this study reflects a better source of Mesoamerican gene pool to improve the common bean growing cultivars, especially those succumbed by ALS, PM, CBB and BCMV diseases (Table 1). Even the identified Andean with moderate resistant for the above diseases could be improved via available resistant bean varieties with the aim to develop the preferred market classes based on region preferences. Additionally, the study shows that extreme rainfall and temperature affects bean grown with disease occurrence and flower abortion respectively, which can cause poor yield. The genetic and environmental differences contribute to the phenotype and sometimes it is used to confirm the GxE interactions among treatment effects (Tabery and Griffiths, 2010). The future approach on these materials will be to carry genotypic sequencing for better correlation between field and laboratory data.

## Conclusion

From this research study, different genotypes expressed trait of resistance under field conditions for the four foliar economic diseases of ALS, CBB, PM and BCMV. Most of the small seeded genotypes dominated the identified genotypes for each trait of focus on the target diseases. This reflects the opportunities to improve the Mesoamerican gene pool across the dry bean research networks. Despite this fact, some of the genotypes expressed trait of resistance under the field but more work needs to be done under the controlled environment with focus placed on the identified genotypes. Apart from disease, other environmental factors like ambient temperature, rainfall variations and relative humidity affected the yield variations.

## CONFLICT OF INTEREST

The authors have not declared any conflict of interests.

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**Supplement 1.** Seed characterization.

| S/N | Genotype | Gene pool | Origin | Market class | Seed color | Seed size |
|---|---|---|---|---|---|---|
| 1 | MAZ 37 | Andean | CIAT breeding line | Red kidney | Red | Large |
| 2 | MAZ 41 | Mesoamerican | CIAT breeding line | Red mottled | Red | Medium |
| 3 | MAZ 42 | Mesoamerican | CIAT breeding line | Red mottled | Red mottled | Medium |
| 4 | MAZ 44 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 5 | MAZ 46 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 6 | MAZ 47 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 7 | MAZ 48 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 8 | MAZ 50 | Mesoamerican | CIAT breeding line | Red mottled | Red mottled | Medium |
| 9 | MAZ 52 | Mesoamerican | CIAT breeding line | Red mottled | Red mottled | Medium |
| 10 | MAZ 59 | Mesoamerican | CIAT breeding line | Red mottled | Red | Medium |
| 11 | MAZ 56 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 12 | MAZ 57 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 13 | MAZ 49 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 14 | MAZ 70 | Mesoamerican | CIAT breeding line | Carioca | Brown striped | Small |
| 15 | MAZ 72 | Andean | CIAT breeding line | Red kidney | Red | Large |
| 16 | MAZ 74 | Andean | CIAT breeding line | Red kidney | Red | Large |
| 17 | MAZ 84 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 18 | MAZ 255 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 19 | DOR 662 | Mesoamerican | CIAT breeding line | Carioca | Brown striped | Small |
| 20 | DOR 708 | Mesoamerican | CIAT breeding line | Red kidney | Purple | Medium |
| 21 | DOR 710 | Mesoamerican | CIAT breeding line | Small red | Red | Small |
| 22 | DOR 711 | Mesoamerican | CIAT breeding line | Small red | Red | Small |
| 23 | DOR 755 | Mesoamerican | CIAT breeding line | Small red | Red | Small |
| 24 | DOR 766 | Mesoamerican | CIAT breeding line | Small red | Red | Small |
| 25 | CN Bunsi (60) | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 26 | CN Bunsi (62) | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 27 | CN Bunsi (63) | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 28 | CN Bunsi (64) | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 29 | CN Bunsi (65) | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 30 | CN Bunsi (66) | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 31 | CN Bunsi (67) | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 32 | CN Bunsi (68) | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 33 | NUA 209 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 34 | NUA 210 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 35 | NUA 272 | Mesoamerican | CIAT breeding line | Yellow | Cream | Medium |
| 36 | NUA 231 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 37 | NUA 244 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 38 | NUA 40 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |

**Supplement 1.** Contd.

| | | | | | | |
|---|---|---|---|---|---|---|
| 39 | NUA 48 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 40 | NUA 57 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 41 | NUA 9 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 42 | NUA 64 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 43 | NUA 110 | Andean | CIAT breeding line | Red kidney | Red | Large |
| 44 | NUA 117 | Mesoamerican | CIAT breeding line | _ | _ | Medium |
| 45 | NUA 212 | Andean | CIAT breeding line | Red mottled | Red mottled | Medium |
| 46 | NUA 213 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 47 | NUA 125 | Mesoamerican | CIAT breeding line | _ | Red | Medium |
| 48 | NUA 232 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 49 | NUA 130 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 50 | NUA 137 | Andean | CIAT breeding line | Red kidney | Red | Large |
| 51 | NUA 156 | Mesoamerican | CIAT breeding line | _ | Red | Medium |
| 52 | NUA 23 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 53 | NUA 11 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 54 | NUA 13 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 55 | NUA 15 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 56 | NUA 16 | Mesoamerican | CIAT breeding line | Small red | Red | Small |
| 57 | NUA 17 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 58 | NUA 18 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 59 | NUA 19 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 60 | NUA 256 | Andean | CIAT breeding line | Speckled sugar | Purple striped | Large |
| 61 | NUA 30 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 62 | NUA 31 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 63 | NUA 134 | Andean | CIAT breeding line | Red kidney | Red | Large |
| 64 | NUA 115 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 65 | NUA 116 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 66 | NUA 129 | Mesoamerican | CIAT breeding line | _ | Red | Medium |
| 67 | NUA 152 | Andean | CIAT breeding line | Red kidney | Red | Large |
| 68 | NUA 158 | Mesoamerican | CIAT breeding line | _ | Black stripe | Medium |
| 69 | NUA 160 | Mesoamerican | CIAT breeding line | Small red | Red | Small |
| 70 | NUA 161 | Andean | CIAT breeding line | Red kidney | Red | Large |
| 71 | NUA 163 | Mesoamerican | CIAT breeding line | Small red | Red | Small |
| 72 | NUA 165 | Mesoamerican | CIAT breeding line | Red mottled | Red mottled | Medium |
| 73 | NUA 39 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 74 | NUA 59 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 75 | NUA 66 | Mesoamerican | CIAT breeding line | Red mottled | Red mottled | Medium |
| 76 | NUA 67 | Andean | CIAT breeding line | Speckled sugar | Purple striped | Large |
| 77 | NUA 79 | Andean | CIAT breeding line | Red kidney | Red | Large |

**Supplement 1.** Contd.

| | | | | | | |
|---|---|---|---|---|---|---|
| 78 | NUA 145 | Andean | CIAT breeding line | _ | Purple | Large |
| 79 | NUA 200 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 80 | NUA 204 | Mesoamerican | CIAT breeding line | Red mottled | Red mottled | Medium |
| 81 | NUA 207 | Mesoamerican | CIAT breeding line | Speckled sugar | Purple striped | Medium |
| 82 | NUA 209 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 83 | NUA 211 | Andean | CIAT breeding line | Speckled sugar | Purple striped | Large |
| 84 | NUA 224 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 85 | NUA 225 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 86 | NUA 226 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 87 | NUA 229 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 88 | NUA 233 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 89 | NUA 235 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 90 | NUA 236 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 91 | NUA 238 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 92 | NUA 239 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 93 | NUA 240 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 94 | NUA 245 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 95 | NUA 257 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 96 | NUA 273 | Andean | CIAT breeding line | Speckled sugar | Purple striped | Large |
| 97 | G 5 | Mesoamerican | Ethiopia | Navy | White | Small |
| 98 | G 23 | Mesoamerican | Ethiopia | Navy | White | Small |
| 99 | G 30 | Mesoamerican | Ethiopia | Navy | White | Small |
| 100 | G 31 | Mesoamerican | Ethiopia | Navy | White | Small |
| 101 | G 60 | Mesoamerican | Ethiopia | Navy | White | Small |
| 102 | G 78 | Mesoamerican | Ethiopia | Navy | White | Small |
| 103 | G 79 | Mesoamerican | Ethiopia | Navy | White | Small |
| 104 | G 87 | Mesoamerican | Ethiopia | Navy | White | Small |
| 105 | G 90 | Mesoamerican | Ethiopia | Navy | White | Small |
| 106 | G 100 | Mesoamerican | Ethiopia | Navy | White | Small |
| 107 | CZ 114-8 | Mesoamerican | Kenya | Small red | Red | Small |
| 108 | CZ 102-24 | Andean | Kenya | Red kidney | Red | Large |
| 109 | CZ 102-29 | Andean | Kenya | Red kidney | Red | Large |
| 110 | CZ 108-27 | Mesoamerican | Kenya | Navy | White | Small |
| 111 | CZ 114-46 | Mesoamerican | Kenya | Small red | Red | Small |
| 112 | CZ 114-50 | Mesoamerican | Kenya | Small red | Red | Small |
| 113 | CZ 114-51 | Mesoamerican | Kenya | Small red | Red | Small |
| 114 | KG 114-177 | Mesoamerican | CIAT breeding line | _ | Purple | Small |
| 115 | KG 114-178 | Mesoamerican | CIAT breeding line | _ | Purple | Small |
| 116 | KG 114-179 | Mesoamerican | CIAT breeding line | Black | Black | Small |

**Supplement 1.** Contd.

| | | | | | | |
|---|---|---|---|---|---|---|
| 117 | KG 114-182 | Mesoamerican | CIAT breeding line | Black | Black | Small |
| 118 | KG 114-185 | Mesoamerican | CIAT breeding line | Small red | Red | Small |
| 119 | KG 4-3 | Mesoamerican | CIAT breeding line | _ | Khak | Small |
| 120 | KG 4-20 | Mesoamerican | CIAT breeding line | Small red | Red | Small |
| 121 | KG 15-6 | Andean | CIAT breeding line | Kablanket | Dotted purple | Large |
| 122 | KG 30-29 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 123 | KG 24-43 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 124 | KG 65-5 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 125 | KG 67-10 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 126 | KG 67-11 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 127 | KG 71-4 | Mesoamerican | CIAT breeding line | _ | Purple | Small |
| 128 | KG 71-5 | Mesoamerican | CIAT breeding line | _ | Purple | Small |
| 129 | KG 97-11 | Andean | CIAT breeding line | Speckled sugar | Brown striped | Large |
| 130 | ZABR 16575-17F22 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 131 | ZABR 16575-24F22 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 132 | ZABR 16575-39F22 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 133 | ZABR 16575-51F22 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 134 | ZABR 16575-60F22 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 135 | ZABR 16575-86F22 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 136 | ZABR 16573-78F22 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 137 | ZABR 16574-46F22 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 138 | ZABR 16576-11F22 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 139 | ZABR 16577-51F22 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 140 | RANJONOMBY | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 141 | Navy line 5 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 142 | Navy line 19 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 143 | Navy line 15 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 144 | Navy line 22 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 145 | Navy line 25 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 146 | Navy line 38 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 147 | Navy line 40 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 148 | Navy line 48 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 149 | Navy line 43 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 150 | Navy line 51 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 151 | Navy line 52 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 152 | Nany line 54 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 153 | RWR 2075 | Andean | Rwanda | Red kidney | Red | Large |
| 154 | RWR 1059 | Mesoamerican | Rwanda | Red mottled | Red mottled | Medium |
| 155 | KABABALA | Mesoamerican | CIAT breeding line | Navy | White | Small |

**Supplement 1.** Contd.

| | | | | | | |
|---|---|---|---|---|---|---|
| 156 | SWP 12 | Mesoamerican | Kenya | Navy | White | Small |
| 157 | SWP 09 | Andean | Kenya | White kidney | White | Large |
| 158 | SWP 10 | Mesoamerican | Kenya | Navy | White | Small |
| 159 | MEXICO 54 | Mesoamerican | CIAT breeding line | Carioca | Cream | Medium |
| 160 | PAN 72 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 161 | JESCA | Andean | Tanzania | Kablanket | Dotted purple | Large |
| 162 | Selian 05 | Mesoamerican | Tanzania | _ | Khak | Small |
| 163 | CC 13 | Mesoamerican | CIAT breeding line | Small red | Red | Small |
| 164 | CC 547 | Mesoamerican | CIAT breeding line | Black | Black | Small |
| 165 | CC 814 | Mesoamerican | CIAT breeding line | Carioca | Brown striped | Small |
| 166 | CC 960 | Mesoamerican | CIAT breeding line | Black | Black | Small |
| 167 | RRN 47 | Mesoamerican | CIAT breeding line | Small red | Red | Small |
| 168 | RRN 48 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 169 | 217/7 | Mesoamerican | CIAT breeding line | _ | Khak | Small |
| 170 | 217/2 | Mesoamerican | CIAT breeding line | _ | Khak | Small |
| 171 | 222/1 | Mesoamerican | CIAT breeding line | Black | Black | Small |
| 172 | 296/6 | Mesoamerican | CIAT breeding line | Carioca | Brown striped | Small |
| 173 | RAZ 36 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 174 | RAZ 44 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 175 | CIM 9313-1 | Mesoamerican | CIAT breeding line | _ | Khak | Small |
| 176 | Lyamungo 90 | Andean | Tanzania | Red mottled | Red mottled | Large |
| 177 | ALS 3 | Mesoamerican | CIAT breeding line | Black | Black | Small |
| 178 | BAT 332 | Mesoamerican | CIAT breeding line | Cream | Cream | Small |
| 179 | IBC 2 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 180 | Awash-1 | Mesoamerican | Ethiopia | Navy | White | Small |
| 181 | Awash Meka | Mesoamerican | Ethiopia | Navy | White | Small |
| 182 | PI 207262 | Mesoamerican | CIAT breeding line | _ | Khak | Small |
| 183 | A 686 | Mesoamerican | CIAT breeding line | Black | Black | Small |
| 184 | A 774 | Mesoamerican | CIAT breeding line | Cream | Cream | Small |
| 185 | A 797 | Andean | CIAT breeding line | Red mottled | Red mottled | Medium |
| 186 | G 5686 | Mesoamerican | CIAT breeding line | Cream | Cream | Large |
| 187 | CANPSULA | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 188 | TU | Mesoamerican | CIAT breeding line | Black | Black | Small |
| 189 | CAL 113 | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 190 | C.202/Hu/3 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 191 | C.202/Hu/11 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 192 | C.2014/Hu/11 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 193 | C.2019/Hu/11 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 194 | C.2017/Hu/11 | Mesoamerican | CIAT breeding line | Navy | White | Small |

**Supplement 1.** Contd.

| | | | | | | |
|---|---|---|---|---|---|---|
| 195 | C.2018/Hu/11 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 196 | MLB 17-89A | Andean | CIAT breeding line | Red mottled | Red mottled | Large |
| 197 | MLB 40-89A | Mesoamerican | CIAT breeding line | _ | Khak | Small |
| 198 | MLB 48-89A | Mesoamerican | CIAT breeding line | _ | Purple | Small |
| 199 | Amendon | Mesoamerican | CIAT breeding line | _ | Dotted purple | Medium |
| 200 | Vax 1 | Mesoamerican | CIAT breeding line | Carioca | Brown striped | Small |
| 201 | Vax 2 | Mesoamerican | CIAT breeding line | Carioca | Brown striped | Small |
| 202 | FLORDEMAYO | Mesoamerican | CIAT breeding line | _ | Dotted purple | Small |
| 203 | FEB 181 | Mesoamerican | CIAT breeding line | Small red | Red | Small |
| 204 | FEB 189 | Mesoamerican | CIAT breeding line | Small red | Red | Small |
| 205 | SAB 662 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 206 | CORNELL 49822 | Mesoamerican | CIAT breeding line | black | Black | Small |
| 207 | SM 133 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 208 | MONT-CALM | Andean | CIAT breeding line | Red kidney | Red | Large |
| 209 | MICHETTE | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 210 | MEXICAN 142 | Mesoamerican | CIAT breeding line | Navy | White | Small |
| 211 | R.K. MICHIGA | Andean | CIAT breeding line | Red kidney | Red | Large |
| 212 | DONTIMOTEA | Mesoamerican | CIAT breeding line | small red | Red | Small |
| 213 | F1 Population | Mesoamerican | CIAT breeding line | Navy | White | Small |

**Supplement 2.** Combined data analysis.

| S/N | Accessions | DFF days | | DM days | | ALS score | | PM score | | CBB score | | BCMV score | | Yield (kg/ha) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *LYA* | *SARI* | *LYA* | *SARI* | *LYA* | *SARI* | *LYA* | *SARI* | *LYA* | *SARI* | *LYA* | *SARI* | *LYA* | *SARI* |
| 1 | 217/2 | 49.25 | 41.50 | 99.75 | 97.75 | 2.00 | 1.50 | 2.75 | 1.25 | 1.75 | 2.25 | 1.00 | 1.25 | 2021.48 | 1244.30 |
| 2 | 222/1 | 49.00 | 43.00 | 103.50 | 102.50 | 2.75 | 1.00 | 2.00 | 1.50 | 1.50 | 2.25 | 3.25 | 3.50 | 1644.77 | 1201.25 |
| 3 | 296/6 | 48.25 | 43.50 | 99.75 | 97.25 | 2.25 | 1.25 | 2.75 | 1.25 | 1.25 | 2.25 | 1.00 | 1.00 | 1513.12 | 1042.66 |
| 4 | A 686 | 48.25 | 43.00 | 101.75 | 102.50 | 2.50 | 1.50 | 2.25 | 2.00 | 1.25 | 3.25 | 5.00 | 4.00 | 1175.31 | 1502.73 |
| 5 | A 774 | 45.25 | 40.00 | 99.25 | 95.00 | 3.25 | 1.75 | 2.00 | 1.50 | 1.00 | 2.75 | 1.00 | 1.75 | 2350.23 | 1613.05 |
| 6 | A 797 | 47.75 | 40.50 | 101.75 | 100.00 | 2.25 | 2.00 | 2.25 | 1.75 | 1.50 | 2.25 | 1.00 | 1.25 | 1488.75 | 813.20 |
| 7 | ALS 3 | 46.25 | 38.50 | 100.50 | 98.75 | 3.50 | 1.25 | 2.75 | 1.00 | 2.00 | 2.00 | 1.00 | 1.00 | 2152.27 | 790.97 |
| 8 | AMENDON | 44.75 | 39.75 | 100.00 | 98.50 | 3.50 | 2.00 | 3.50 | 2.00 | 1.75 | 2.50 | 1.50 | 1.50 | 1158.44 | 1030.86 |
| 9 | Awash Meka | 49.25 | 44.25 | 102.50 | 100.50 | 1.50 | 2.00 | 2.25 | 1.50 | 3.75 | 2.00 | 1.00 | 1.25 | 1952.03 | 992.27 |
| 10 | Awash-1 | 47.75 | 41.00 | 101.50 | 99.75 | 2.00 | 1.50 | 1.50 | 1.25 | 2.75 | 2.00 | 1.25 | 1.00 | 1339.06 | 1201.70 |
| 11 | BAT 332 | 49.75 | 43.25 | 101.50 | 99.75 | 2.25 | 2.00 | 2.50 | 1.00 | 1.75 | 2.25 | 1.00 | 1.00 | 2033.44 | 749.06 |
| 12 | C.2014/Hu/11 | 44.50 | 37.75 | 99.75 | 101.50 | 2.50 | 1.50 | 2.50 | 2.25 | 3.00 | 2.00 | 1.00 | 1.00 | 1292.58 | 1005.00 |

**Supplement 2.** Contd.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | C.2017/Hu/11 | 49.00 | 43.00 | 103.25 | 102.75 | 2.50 | 2.75 | 3.00 | 1.50 | 3.00 | 1.50 | 1.00 | 1.00 | 1576.25 | 872.73 |
| 14 | C.2018/Hu/11 | 45.00 | 39.50 | 101.00 | 101.75 | 2.50 | 2.00 | 1.50 | 1.50 | 2.50 | 2.00 | 1.00 | 1.50 | 759.06 | 1117.89 |
| 15 | C.2019/Hu/11 | 47.25 | 42.50 | 101.75 | 105.50 | 2.00 | 2.00 | 2.25 | 1.00 | 3.25 | 2.00 | 1.00 | 1.00 | 1678.75 | 808.52 |
| 16 | C.202/Hu/3 | 45.00 | 38.75 | 99.00 | 101.00 | 1.50 | 2.75 | 2.25 | 1.00 | 3.50 | 2.00 | 1.00 | 1.50 | 1093.28 | 672.03 |
| 17 | CAL 113 | 42.25 | 39.00 | 97.00 | 96.00 | 3.50 | 2.25 | 2.50 | 2.00 | 2.25 | 3.00 | 1.00 | 1.25 | 1418.37 | 856.68 |
| 18 | CANPSULA | 46.00 | 38.75 | 102.25 | 100.75 | 2.00 | 1.75 | 2.25 | 1.00 | 2.75 | 1.75 | 1.00 | 1.00 | 1065.31 | 961.72 |
| 19 | CC 13 | 49.25 | 43.00 | 103.00 | 98.50 | 3.00 | 1.50 | 2.00 | 2.00 | 1.25 | 2.50 | 1.75 | 1.75 | 1806.56 | 1259.92 |
| 20 | CC 547 | 49.50 | 43.00 | 102.00 | 98.50 | 2.00 | 1.50 | 2.50 | 1.25 | 1.25 | 2.00 | 1.25 | 1.00 | 1918.91 | 1342.34 |
| 21 | CC 814 | 47.50 | 42.00 | 97.75 | 98.75 | 2.25 | 1.00 | 2.50 | 1.50 | 1.75 | 2.50 | 1.00 | 1.50 | 1974.53 | 715.78 |
| 22 | CC 906 | 47.50 | 44.50 | 104.00 | 97.50 | 2.50 | 1.50 | 2.00 | 1.00 | 1.25 | 2.25 | 2.75 | 3.75 | 1535.39 | 1160.86 |
| 23 | CIM 9313-1 | 49.75 | 44.25 | 100.50 | 96.75 | 2.25 | 1.75 | 2.25 | 1.00 | 1.75 | 2.00 | 1.00 | 1.00 | 1557.81 | 1442.42 |
| 24 | CN Bunsi (60) | 49.00 | 42.00 | 103.00 | 100.25 | 1.50 | 1.75 | 1.50 | 1.50 | 2.25 | 1.75 | 1.00 | 1.25 | 776.87 | 852.66 |
| 25 | CN Bunsi (62) | 49.25 | 42.75 | 104.50 | 100.75 | 1.75 | 1.50 | 3.00 | 1.00 | 2.50 | 2.50 | 1.00 | 1.00 | 1653.05 | 636.41 |
| 26 | CN Bunsi (63) | 44.50 | 39.50 | 98.00 | 99.75 | 2.00 | 1.75 | 1.50 | 1.25 | 2.75 | 1.75 | 1.25 | 1.00 | 1040.94 | 1121.56 |
| 27 | CN Bunsi (64) | 46.75 | 40.25 | 98.75 | 99.25 | 1.75 | 1.25 | 1.25 | 1.00 | 3.00 | 2.00 | 1.00 | 1.00 | 1105.08 | 653.75 |
| 28 | CN Bunsi (65) | 45.00 | 42.75 | 97.25 | 99.25 | 2.75 | 1.75 | 2.75 | 1.25 | 2.50 | 1.25 | 1.00 | 1.00 | 1174.30 | 855.94 |
| 29 | CN Bunsi (66) | 48.50 | 41.00 | 99.75 | 95.00 | 2.50 | 2.00 | 2.75 | 2.75 | 2.25 | 2.25 | 1.00 | 1.00 | 2309.30 | 895.56 |
| 30 | CN Bunsi (67) | 44.75 | 39.50 | 98.25 | 95.25 | 2.00 | 2.00 | 2.00 | 1.50 | 2.75 | 2.00 | 1.00 | 1.50 | 1192.03 | 1037.69 |
| 31 | CN Bunsi (68) | 50.25 | 42.25 | 104.50 | 100.00 | 1.50 | 2.50 | 2.50 | 1.75 | 2.75 | 2.25 | 1.00 | 1.75 | 1330.00 | 862.97 |
| 32 | CORNELL 49242 | 48.25 | 43.00 | 103.75 | 102.75 | 3.00 | 1.00 | 3.25 | 2.00 | 1.50 | 2.50 | 1.00 | 1.00 | 1833.12 | 675.70 |
| 33 | CZ 102-24 | 39.75 | 34.50 | 95.75 | 94.75 | 4.25 | 2.75 | 2.00 | 1.25 | 1.75 | 2.50 | 1.00 | 1.00 | 1950.43 | 1281.78 |
| 34 | CZ 102-29 | 42.25 | 36.00 | 97.25 | 99.50 | 3.25 | 2.00 | 2.75 | 1.25 | 1.75 | 1.50 | 1.00 | 1.25 | 931.73 | 922.55 |
| 35 | CZ 108-27 | 47.00 | 39.25 | 100.00 | 98.00 | 2.00 | 2.00 | 2.00 | 1.75 | 1.50 | 2.00 | 1.00 | 1.75 | 817.60 | 971.16 |
| 36 | CZ 114-46 | 40.25 | 35.25 | 93.50 | 98.75 | 3.75 | 1.50 | 1.75 | 1.25 | 1.50 | 2.25 | 1.00 | 1.00 | 1462.84 | 1158.22 |
| 37 | CZ 114-50 | 40.25 | 34.75 | 94.75 | 99.00 | 2.50 | 1.25 | 2.75 | 2.00 | 2.00 | 2.00 | 1.00 | 1.00 | 1474.09 | 1425.10 |
| 38 | CZ 114-51 | 41.00 | 36.75 | 95.75 | 72.25 | 3.50 | 2.25 | 2.50 | 1.25 | 1.75 | 2.50 | 1.00 | 1.25 | 1194.47 | 1268.41 |
| 39 | CZ 114-8 | 43.00 | 38.25 | 97.25 | 98.25 | 3.00 | 2.50 | 2.50 | 2.25 | 1.75 | 2.50 | 1.00 | 1.75 | 1057.69 | 1271.36 |
| 40 | DONTIMOTEO | 47.25 | 38.00 | 103.50 | 99.50 | 2.00 | 3.25 | 2.50 | 2.25 | 1.50 | 2.50 | 1.00 | 2.25 | 568.61 | 604.92 |
| 41 | DOR 662 | 47.00 | 41.75 | 100.75 | 98.50 | 1.75 | 2.25 | 1.75 | 1.00 | 1.00 | 1.50 | 1.00 | 1.00 | 1209.06 | 875.70 |
| 42 | DOR 708 | 47.50 | 42.00 | 100.25 | 102.25 | 2.50 | 1.50 | 2.50 | 1.25 | 1.25 | 1.75 | 1.00 | 1.00 | 1257.27 | 1141.02 |
| 43 | DOR 710 | 45.75 | 40.50 | 101.00 | 98.25 | 2.75 | 1.50 | 1.75 | 1.00 | 4.00 | 3.50 | 1.25 | 1.25 | 1888.98 | 1437.03 |
| 44 | DOR 711 | 49.00 | 41.00 | 101.25 | 103.00 | 2.25 | 2.00 | 2.50 | 1.00 | 1.75 | 1.00 | 1.00 | 1.00 | 2027.27 | 707.89 |
| 45 | DOR 755 | 49.50 | 44.00 | 105.25 | 103.25 | 1.75 | 1.00 | 2.50 | 1.75 | 1.50 | 3.00 | 4.25 | 3.00 | 2001.87 | 1088.67 |
| 46 | DOR 766 | 45.75 | 39.75 | 100.25 | 99.75 | 2.25 | 1.25 | 2.50 | 1.00 | 1.25 | 1.25 | 1.50 | 1.00 | 2359.37 | 1070.47 |
| 47 | DOR 771 | 48.25 | 41.75 | 101.25 | 101.25 | 2.25 | 2.00 | 2.25 | 1.50 | 1.00 | 1.00 | 1.75 | 1.00 | 1780.78 | 1180.47 |
| 48 | F1POPULATION | 44.75 | 41.50 | 100.00 | 99.00 | 2.00 | 1.50 | 1.50 | 1.00 | 3.25 | 1.75 | 1.50 | 1.00 | 1117.73 | 714.87 |
| 49 | FEB 181 | 47.50 | 41.75 | 101.25 | 100.00 | 2.75 | 2.00 | 2.75 | 1.50 | 1.25 | 2.50 | 2.25 | 1.50 | 1459.30 | 977.95 |

**Supplement 2.** Contd.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 | FEB 189 | 46.50 | 39.00 | 100.25 | 98.25 | 2.00 | 1.75 | 1.00 | 1.75 | 1.00 | 2.25 | 1.00 | 1.75 | 2590.31 | 1662.94 |
| 51 | FLOR DE MAYO | 46.00 | 39.25 | 103.75 | 103.75 | 4.00 | 1.25 | 2.00 | 1.00 | 3.00 | 3.00 | 3.00 | 3.75 | 915.87 | 678.75 |
| 52 | G 100 | 44.25 | 39.50 | 96.75 | 93.75 | 2.00 | 1.50 | 2.25 | 1.75 | 3.50 | 2.25 | 1.00 | 1.00 | 1103.05 | 1084.05 |
| 53 | G 23 | 48.50 | 40.50 | 101.50 | 98.75 | 2.50 | 2.25 | 3.00 | 2.25 | 2.50 | 1.50 | 1.00 | 1.00 | 1830.78 | 1185.62 |
| 54 | G 30 | 44.75 | 40.25 | 96.75 | 100.25 | 2.00 | 1.75 | 1.50 | 1.00 | 3.25 | 2.00 | 1.00 | 1.00 | 1334.45 | 1045.55 |
| 55 | G 31 | 46.25 | 44.00 | 105.50 | 101.50 | 1.75 | 1.50 | 1.75 | 1.50 | 3.75 | 1.75 | 1.00 | 1.75 | 1412.50 | 925.23 |
| 56 | G 5 | 46.00 | 39.75 | 100.00 | 100.25 | 1.75 | 2.00 | 1.75 | 1.25 | 2.50 | 2.00 | 1.50 | 1.00 | 1174.61 | 981.09 |
| 57 | G 5686 | 41.00 | 37.00 | 98.00 | 97.75 | 3.00 | 2.00 | 3.00 | 2.00 | 1.75 | 2.00 | 1.00 | 2.00 | 1095.23 | 1092.78 |
| 58 | G 60 | 46.00 | 39.50 | 99.50 | 101.00 | 1.50 | 2.00 | 1.50 | 1.00 | 3.50 | 1.75 | 1.00 | 1.00 | 1910.31 | 846.33 |
| 59 | G 78 | 49.00 | 43.00 | 103.25 | 99.25 | 1.75 | 1.50 | 2.50 | 1.25 | 3.50 | 1.75 | 1.00 | 1.00 | 1394.84 | 1084.06 |
| 60 | G 79 | 46.50 | 42.00 | 101.75 | 102.00 | 2.00 | 2.50 | 2.00 | 1.75 | 3.50 | 2.00 | 1.00 | 2.25 | 1178.44 | 842.75 |
| 61 | G 87 | 48.00 | 41.50 | 102.75 | 99.00 | 1.75 | 2.00 | 3.00 | 2.25 | 3.00 | 2.25 | 1.00 | 1.25 | 978.44 | 778.91 |
| 62 | G 90 | 42.75 | 35.75 | 99.00 | 99.50 | 3.00 | 2.75 | 3.25 | 1.25 | 2.75 | 3.00 | 1.00 | 1.25 | 467.97 | 857.97 |
| 63 | IBC 2 | 45.00 | 42.00 | 104.25 | 98.50 | 1.50 | 2.00 | 1.50 | 1.75 | 2.50 | 2.75 | 1.25 | 1.75 | 1277.19 | 793.81 |
| 64 | JESCA | 35.00 | 34.50 | 93.50 | 92.25 | 4.00 | 2.25 | 2.50 | 1.50 | 1.50 | 2.00 | 1.00 | 1.25 | 1435.00 | 1319.42 |
| 65 | KABALABALA | 47.75 | 40.00 | 101.00 | 97.00 | 2.50 | 1.00 | 1.75 | 1.75 | 1.50 | 2.00 | 1.00 | 1.00 | 448.94 | 830.00 |
| 66 | KG 114-177 | 42.75 | 37.25 | 97.25 | 95.75 | 2.75 | 1.50 | 2.50 | 1.50 | 2.50 | 2.00 | 1.00 | 1.00 | 1628.46 | 1545.24 |
| 67 | KG 114-178 | 44.75 | 40.00 | 97.25 | 96.00 | 2.25 | 2.00 | 3.25 | 1.25 | 2.25 | 1.75 | 1.00 | 1.25 | 1047.98 | 1214.76 |
| 68 | KG 114-179 | 43.25 | 38.00 | 98.50 | 97.00 | 2.50 | 2.00 | 2.50 | 1.75 | 2.00 | 1.75 | 1.00 | 1.25 | 1341.87 | 1318.12 |
| 69 | KG 114-182 | 42.25 | 37.25 | 97.25 | 72.75 | 2.50 | 1.75 | 2.75 | 2.00 | 1.25 | 2.25 | 1.25 | 1.00 | 1639.62 | 1673.37 |
| 70 | KG 114-185 | 43.50 | 38.25 | 95.75 | 97.25 | 3.75 | 2.25 | 2.25 | 1.50 | 1.00 | 2.00 | 1.25 | 1.00 | 1683.41 | 1400.67 |
| 71 | KG 15-6 | 43.00 | 38.00 | 99.25 | 98.00 | 3.75 | 2.50 | 2.75 | 1.25 | 1.50 | 3.00 | 1.00 | 1.25 | 1777.93 | 1298.85 |
| 72 | KG 24-43 | 46.00 | 43.00 | 103.75 | 102.00 | 2.75 | 1.75 | 2.00 | 2.00 | 1.75 | 2.25 | 1.00 | 1.50 | 1020.29 | 826.88 |
| 73 | KG 30-29 | 49.00 | 43.00 | 103.25 | 103.00 | 1.50 | 1.00 | 2.00 | 1.75 | 1.75 | 2.00 | 1.75 | 1.25 | 1477.69 | 1035.77 |
| 74 | KG 4-20 | 42.25 | 37.25 | 96.50 | 100.50 | 3.25 | 1.50 | 3.00 | 2.50 | 1.25 | 1.25 | 1.00 | 1.25 | 1250.38 | 1194.90 |
| 75 | KG 4-3 | 44.75 | 39.75 | 97.75 | 99.50 | 3.00 | 2.00 | 2.50 | 1.50 | 1.50 | 2.50 | 1.00 | 1.00 | 1820.14 | 1166.20 |
| 76 | KG 67-10 | 48.00 | 39.50 | 101.25 | 101.75 | 2.50 | 2.00 | 2.75 | 1.50 | 3.00 | 1.75 | 1.00 | 1.00 | 1394.69 | 686.14 |
| 77 | KG 67-11 | 45.25 | 38.75 | 98.50 | 100.75 | 1.75 | 2.75 | 1.50 | 1.75 | 2.50 | 1.75 | 1.00 | 1.50 | 1278.67 | 1049.61 |
| 78 | KG 67-5 | 44.25 | 41.50 | 99.50 | 98.75 | 1.75 | 2.00 | 3.75 | 1.75 | 2.50 | 1.50 | 1.00 | 1.75 | 1887.89 | 861.48 |
| 79 | KG 71-4 | 42.50 | 37.25 | 96.25 | 95.25 | 2.75 | 2.00 | 1.75 | 1.25 | 1.75 | 1.75 | 1.00 | 1.00 | 2056.49 | 1392.88 |
| 80 | KG 71-5 | 42.75 | 37.25 | 95.75 | 96.50 | 3.00 | 1.50 | 1.50 | 1.50 | 1.50 | 2.50 | 2.00 | 1.00 | 1709.81 | 1351.73 |
| 81 | KG 97-11 | 47.50 | 42.75 | 103.00 | 101.00 | 2.25 | 1.50 | 3.00 | 1.75 | 2.50 | 2.75 | 1.00 | 2.25 | 1686.72 | 1001.41 |
| 82 | LYAMUNGU 90 | 38.00 | 33.50 | 94.50 | 93.00 | 3.00 | 2.00 | 3.00 | 2.25 | 1.25 | 3.00 | 1.00 | 1.00 | 1078.27 | 947.21 |
| 83 | MAZ 37 | 39.50 | 37.00 | 96.50 | 97.75 | 3.25 | 2.25 | 4.00 | 2.00 | 1.50 | 2.00 | 1.00 | 1.00 | 1100.23 | 1057.27 |
| 84 | MAZ 41 | 40.25 | 36.25 | 97.00 | 99.50 | 3.75 | 2.25 | 3.00 | 1.25 | 1.50 | 1.50 | 1.00 | 1.25 | 732.50 | 1122.19 |
| 85 | MAZ 42 | 42.00 | 37.00 | 99.25 | 98.25 | 4.00 | 2.00 | 2.75 | 1.00 | 1.25 | 2.50 | 1.00 | 1.00 | 884.14 | 885.94 |
| 86 | MAZ 44 | 40.00 | 33.25 | 99.00 | 96.50 | 4.25 | 2.50 | 2.25 | 1.25 | 1.25 | 2.00 | 1.25 | 1.00 | 960.08 | 911.72 |

**Supplement 2.** Contd.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 87 | MAZ 46 | 43.25 | 37.00 | 98.50 | 99.25 | 4.00 | 2.25 | 3.00 | 2.00 | 1.50 | 3.25 | 1.50 | 1.50 | 1596.09 | 929.92 |
| 88 | MAZ 47 | 43.25 | 38.50 | 98.25 | 96.25 | 3.75 | 2.50 | 2.75 | 2.25 | 2.25 | 3.00 | 1.50 | 1.50 | 1102.19 | 1275.86 |
| 89 | MAZ 48 | 39.50 | 33.75 | 98.75 | 98.25 | 3.50 | 2.50 | 4.25 | 2.25 | 1.75 | 2.50 | 1.00 | 1.75 | 1829.61 | 1330.86 |
| 90 | MAZ 49 | 41.25 | 35.00 | 99.50 | 97.50 | 3.50 | 2.25 | 2.00 | 1.25 | 1.75 | 2.25 | 1.00 | 1.25 | 1229.69 | 1392.50 |
| 91 | MAZ 50 | 41.25 | 35.00 | 98.75 | 99.75 | 4.25 | 2.25 | 2.50 | 1.25 | 1.50 | 2.50 | 1.00 | 1.25 | 1227.42 | 1095.00 |
| 92 | MAZ 52 | 41.50 | 38.25 | 100.00 | 101.00 | 3.50 | 2.00 | 2.50 | 2.00 | 1.50 | 2.25 | 2.50 | 2.00 | 1201.17 | 1160.16 |
| 93 | MAZ 55 | 40.25 | 33.25 | 95.25 | 97.50 | 3.75 | 2.25 | 3.25 | 1.25 | 1.75 | 1.25 | 1.25 | 1.25 | 1166.87 | 1173.94 |
| 94 | MAZ 56 | 42.00 | 40.75 | 98.25 | 99.50 | 3.50 | 2.00 | 3.75 | 2.00 | 1.50 | 2.00 | 1.00 | 1.00 | 655.70 | 897.19 |
| 95 | MAZ 57 | 41.00 | 35.25 | 97.00 | 100.75 | 3.75 | 2.75 | 4.00 | 2.25 | 1.50 | 2.50 | 1.00 | 1.00 | 1242.58 | 1203.98 |
| 96 | MAZ 59 | 40.00 | 33.50 | 95.50 | 94.00 | 4.50 | 2.50 | 3.25 | 1.25 | 1.25 | 2.00 | 4.00 | 1.75 | 971.87 | 836.48 |
| 97 | MAZ 70 | 45.75 | 40.75 | 102.25 | 101.75 | 2.50 | 1.00 | 1.75 | 1.00 | 1.50 | 3.25 | 1.00 | 1.00 | 572.42 | 1421.95 |
| 98 | MAZ 72 | 41.50 | 35.50 | 97.75 | 96.50 | 3.25 | 1.75 | 4.00 | 2.50 | 1.75 | 2.50 | 1.00 | 1.00 | 479.61 | 731.02 |
| 99 | MAZ 74 | 41.25 | 37.00 | 97.25 | 96.75 | 3.25 | 2.75 | 3.75 | 2.25 | 1.00 | 2.50 | 1.00 | 1.00 | 771.17 | 607.11 |
| 100 | MAZ 84 | 40.50 | 35.00 | 95.50 | 95.50 | 4.00 | 2.50 | 4.00 | 1.25 | 1.25 | 1.75 | 1.00 | 1.25 | 1151.33 | 991.33 |
| 101 | MEX 54 | 46.00 | 41.50 | 101.50 | 99.75 | 2.25 | 1.75 | 1.50 | 1.00 | 2.50 | 3.00 | 1.25 | 1.25 | 2660.62 | 789.61 |
| 102 | MEXICAN 142 | 48.50 | 41.50 | 104.50 | 103.50 | 1.75 | 2.25 | 2.25 | 1.25 | 2.75 | 1.50 | 1.00 | 1.75 | 1901.64 | 750.70 |
| 103 | MICHETTE | 45.00 | 38.25 | 99.25 | 97.50 | 3.25 | 2.75 | 1.00 | 1.50 | 1.25 | 2.25 | 1.50 | 2.00 | 644.53 | 645.94 |
| 104 | MLB 17-89A | 46.50 | 40.25 | 100.25 | 97.75 | 2.75 | 1.50 | 4.50 | 2.75 | 1.50 | 2.50 | 1.75 | 1.00 | 576.80 | 1186.80 |
| 105 | MLB 40-89A | 49.00 | 45.75 | 100.75 | 96.75 | 2.25 | 1.75 | 1.75 | 1.00 | 1.50 | 1.75 | 1.00 | 1.00 | 1702.81 | 926.80 |
| 106 | MLB 48-89A | 45.75 | 42.00 | 102.25 | 101.75 | 2.75 | 1.00 | 3.00 | 1.75 | 1.00 | 2.50 | 4.25 | 3.25 | 1423.36 | 1096.95 |
| 107 | MONT-CALM | 39.00 | 34.00 | 95.00 | 94.00 | 4.00 | 3.50 | 4.50 | 2.25 | 1.50 | 2.50 | 1.00 | 1.25 | 638.83 | 744.77 |
| 108 | Navy line 15 | 42.25 | 41.00 | 102.00 | 104.50 | 2.25 | 2.25 | 2.25 | 1.75 | 2.50 | 2.50 | 1.50 | 2.75 | 1043.59 | 969.53 |
| 109 | Navy line 19 | 45.50 | 41.75 | 100.25 | 100.75 | 2.00 | 2.00 | 2.00 | 1.50 | 4.25 | 2.50 | 1.00 | 1.50 | 1054.61 | 872.86 |
| 110 | Navy line 22 | 44.50 | 40.25 | 96.75 | 96.00 | 2.25 | 1.50 | 1.25 | 2.00 | 1.75 | 2.25 | 1.00 | 1.00 | 1498.67 | 1005.48 |
| 111 | Navy line 25 | 50.50 | 43.25 | 104.25 | 99.75 | 1.75 | 2.00 | 3.50 | 2.00 | 2.75 | 2.00 | 1.00 | 1.75 | 1202.19 | 1058.31 |
| 112 | Navy line 38 | 42.00 | 38.25 | 100.25 | 98.25 | 2.25 | 1.75 | 1.75 | 1.50 | 3.00 | 1.50 | 1.00 | 1.50 | 1973.75 | 1241.09 |
| 113 | Navy line 40 | 40.00 | 34.00 | 95.75 | 85.50 | 3.00 | 2.50 | 1.50 | 1.25 | 1.75 | 1.75 | 1.00 | 1.00 | 1204.61 | 1406.87 |
| 114 | Navy line 43 | 44.75 | 41.50 | 97.00 | 96.75 | 2.75 | 2.25 | 2.00 | 1.25 | 3.25 | 1.75 | 1.00 | 1.25 | 1248.44 | 1115.00 |
| 115 | Navy line 48 | 46.50 | 42.50 | 101.75 | 103.00 | 2.00 | 1.25 | 2.25 | 1.50 | 2.25 | 2.00 | 1.00 | 1.00 | 1629.53 | 743.98 |
| 116 | Navy line 5 | 45.00 | 39.00 | 104.50 | 104.50 | 2.25 | 2.00 | 3.25 | 1.00 | 2.50 | 2.75 | 1.00 | 1.25 | 748.91 | 605.62 |
| 117 | Navy line 51 | 45.50 | 42.50 | 101.75 | 98.25 | 2.50 | 1.75 | 3.75 | 1.25 | 2.50 | 1.50 | 1.00 | 1.25 | 1639.37 | 1086.95 |
| 118 | Navy line 52 | 48.00 | 44.50 | 102.25 | 101.75 | 2.25 | 1.50 | 1.75 | 1.25 | 2.75 | 2.25 | 1.00 | 1.00 | 1703.52 | 798.41 |
| 119 | Navy line 54 | 45.00 | 37.00 | 100.00 | 97.75 | 2.50 | 2.00 | 4.25 | 1.25 | 3.25 | 1.75 | 1.00 | 1.00 | 1257.03 | 996.84 |
| 120 | NUA 11 | 42.50 | 40.00 | 98.75 | 100.75 | 3.00 | 2.50 | 2.25 | 1.50 | 3.25 | 3.00 | 1.50 | 2.00 | 1155.62 | 914.87 |
| 121 | NUA 110 | 39.00 | 35.75 | 96.00 | 98.00 | 2.25 | 2.00 | 5.50 | 2.00 | 2.50 | 2.50 | 1.00 | 1.00 | 727.50 | 724.06 |
| 122 | NUA 116 | 45.00 | 40.50 | 100.75 | 101.25 | 1.75 | 1.50 | 3.00 | 1.50 | 3.75 | 1.75 | 1.50 | 1.25 | 1051.02 | 1206.56 |
| 123 | NUA 117 | 46.00 | 39.00 | 102.00 | 100.25 | 2.25 | 1.50 | 3.50 | 2.00 | 3.00 | 2.75 | 1.00 | 1.50 | 976.09 | 469.30 |

**Supplement 2.** Contd.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 124 | NUA 125 | 40.75 | 34.25 | 99.00 | 100.00 | 3.00 | 2.00 | 4.75 | 1.00 | 1.75 | 2.75 | 1.00 | 1.25 | 1294.61 | 1020.78 |
| 125 | NUA 129 | 38.75 | 35.25 | 95.75 | 96.25 | 2.50 | 3.00 | 3.00 | 1.25 | 3.00 | 3.25 | 1.00 | 2.00 | 677.89 | 723.58 |
| 126 | NUA 13 | 44.25 | 35.75 | 101.50 | 94.00 | 2.50 | 2.00 | 3.00 | 1.25 | 2.75 | 3.00 | 1.00 | 3.75 | 819.45 | 580.94 |
| 127 | NUA 130 | 41.50 | 35.25 | 95.50 | 100.75 | 2.25 | 2.25 | 4.25 | 2.25 | 2.50 | 2.75 | 2.00 | 2.25 | 915.08 | 658.05 |
| 128 | NUA 134 | 42.25 | 37.00 | 100.00 | 102.75 | 2.25 | 2.00 | 2.25 | 2.00 | 2.75 | 3.00 | 1.25 | 2.75 | 1121.72 | 840.94 |
| 129 | NUA 137 | 36.50 | 37.75 | 97.25 | 97.25 | 2.25 | 2.50 | 6.00 | 3.00 | 2.00 | 3.25 | 1.00 | 2.00 | 1016.87 | 772.16 |
| 130 | NUA 145 | 43.25 | 40.00 | 99.50 | 96.50 | 3.50 | 2.25 | 5.00 | 1.25 | 2.75 | 1.75 | 1.00 | 1.75 | 758.28 | 569.22 |
| 131 | NUA 15 | 35.75 | 34.75 | 96.75 | 95.50 | 2.50 | 2.25 | 5.00 | 1.75 | 1.75 | 2.50 | 1.00 | 1.00 | 1056.09 | 1111.72 |
| 132 | NUA 152 | 43.75 | 38.25 | 100.25 | 99.00 | 2.75 | 2.00 | 3.00 | 1.25 | 3.50 | 3.00 | 1.00 | 1.25 | 1629.69 | 1257.89 |
| 133 | NUA 156 | 43.25 | 40.50 | 99.25 | 100.50 | 2.00 | 1.50 | 4.25 | 2.00 | 3.25 | 3.00 | 1.00 | 2.00 | 416.80 | 455.70 |
| 134 | NUA 158 | 46.50 | 41.00 | 98.25 | 100.00 | 3.25 | 2.00 | 3.00 | 1.00 | 3.00 | 3.25 | 1.00 | 1.25 | 616.95 | 584.83 |
| 135 | NUA 16 | 42.75 | 40.00 | 98.25 | 99.25 | 1.75 | 1.50 | 2.25 | 1.50 | 3.25 | 1.75 | 1.00 | 1.00 | 2003.67 | 1581.41 |
| 136 | NUA 160 | 43.75 | 38.00 | 98.00 | 100.50 | 2.00 | 1.75 | 3.50 | 1.75 | 3.25 | 3.00 | 1.00 | 1.00 | 1210.70 | 1036.09 |
| 137 | NUA 161 | 43.25 | 38.50 | 102.00 | 99.00 | 3.00 | 2.75 | 1.50 | 2.00 | 2.00 | 3.75 | 1.25 | 2.50 | 444.22 | 352.66 |
| 138 | NUA 163 | 44.00 | 38.25 | 99.50 | 101.25 | 2.75 | 2.50 | 3.50 | 1.25 | 2.75 | 4.00 | 1.00 | 2.25 | 1042.03 | 723.83 |
| 139 | NUA 165 | 42.75 | 36.50 | 97.50 | 96.75 | 3.00 | 2.25 | 3.75 | 1.25 | 3.25 | 1.50 | 1.00 | 1.75 | 651.64 | 758.12 |
| 140 | NUA 17 | 43.50 | 38.50 | 98.75 | 97.75 | 2.75 | 2.50 | 2.00 | 1.75 | 3.25 | 3.00 | 1.00 | 2.00 | 1392.19 | 1360.39 |
| 141 | NUA 18 | 43.25 | 35.50 | 97.25 | 97.50 | 2.25 | 2.25 | 2.50 | 1.00 | 3.50 | 2.00 | 1.00 | 1.25 | 1574.37 | 1002.50 |
| 142 | NUA 19 | 44.75 | 38.00 | 101.00 | 97.00 | 3.00 | 2.00 | 2.75 | 1.25 | 2.75 | 1.50 | 1.50 | 3.00 | 559.30 | 907.73 |
| 143 | NUA 200 | 43.00 | 36.75 | 97.75 | 95.50 | 2.50 | 2.00 | 4.00 | 2.25 | 3.25 | 2.75 | 1.00 | 1.25 | 967.81 | 978.12 |
| 144 | NUA 204 | 42.00 | 34.25 | 100.00 | 102.50 | 2.25 | 1.50 | 2.50 | 2.00 | 2.50 | 2.50 | 2.50 | 1.75 | 1048.28 | 1131.87 |
| 145 | NUA 207 | 44.25 | 36.25 | 101.25 | 100.25 | 2.25 | 2.00 | 3.25 | 1.25 | 4.50 | 3.25 | 1.00 | 1.25 | 1207.81 | 1442.03 |
| 146 | NUA 209 | 46.50 | 39.00 | 100.00 | 99.00 | 3.00 | 1.75 | 3.25 | 1.00 | 2.50 | 1.50 | 1.00 | 1.25 | 1424.53 | 1012.66 |
| 147 | NUA 210 | 43.00 | 40.50 | 99.50 | 97.50 | 2.75 | 2.00 | 2.25 | 1.00 | 3.25 | 2.75 | 1.00 | 2.25 | 1074.37 | 861.09 |
| 148 | NUA 211 | 40.25 | 35.00 | 98.25 | 100.25 | 3.25 | 2.50 | 3.25 | 1.25 | 2.75 | 3.00 | 1.00 | 1.50 | 972.34 | 1527.66 |
| 149 | NUA 212 | 42.50 | 36.25 | 96.00 | 97.25 | 2.50 | 2.25 | 3.50 | 1.75 | 2.50 | 1.50 | 1.00 | 1.25 | 795.47 | 1351.09 |
| 150 | NUA 213 | 40.75 | 34.50 | 98.25 | 76.75 | 2.50 | 2.25 | 4.75 | 2.25 | 2.00 | 2.00 | 1.00 | 1.50 | 1264.45 | 771.80 |
| 151 | NUA 224 | 42.75 | 38.00 | 101.25 | 100.50 | 2.75 | 2.25 | 3.50 | 2.00 | 3.25 | 3.00 | 1.00 | 2.00 | 1622.50 | 1219.92 |
| 152 | NUA 225 | 43.00 | 39.50 | 97.50 | 99.50 | 2.50 | 2.00 | 2.00 | 1.25 | 3.50 | 2.50 | 1.00 | 1.25 | 601.41 | 1040.78 |
| 153 | NUA 226 | 46.25 | 40.25 | 100.75 | 97.50 | 2.25 | 2.00 | 2.00 | 2.50 | 4.00 | 2.50 | 1.00 | 1.00 | 1025.00 | 759.45 |
| 154 | NUA 229 | 46.00 | 40.00 | 101.25 | 101.00 | 2.25 | 2.00 | 2.50 | 1.00 | 3.00 | 3.00 | 1.00 | 1.25 | 1349.14 | 1047.27 |
| 155 | NUA 23 | 41.25 | 37.00 | 98.00 | 97.25 | 3.00 | 2.75 | 2.75 | 1.50 | 3.25 | 2.50 | 1.00 | 2.00 | 744.84 | 840.94 |
| 156 | NUA 231 | 47.00 | 41.75 | 100.75 | 101.25 | 1.75 | 2.25 | 2.25 | 1.00 | 3.00 | 3.00 | 1.50 | 1.25 | 1033.36 | 1037.81 |
| 157 | NUA 232 | 46.25 | 38.50 | 102.25 | 100.25 | 2.00 | 2.25 | 1.75 | 1.00 | 2.50 | 2.25 | 1.00 | 1.00 | 937.42 | 1203.59 |
| 158 | NUA 233 | 44.25 | 39.00 | 101.25 | 103.25 | 2.50 | 2.25 | 2.75 | 1.00 | 2.25 | 1.75 | 1.00 | 1.50 | 1917.66 | 1122.42 |
| 159 | NUA 235 | 40.75 | 34.75 | 96.50 | 94.75 | 2.25 | 2.25 | 3.75 | 2.00 | 3.00 | 2.50 | 1.00 | 1.50 | 1020.62 | 1098.98 |
| 160 | NUA 236 | 42.75 | 35.50 | 98.00 | 101.00 | 2.75 | 2.25 | 4.50 | 1.75 | 2.25 | 2.50 | 1.00 | 1.25 | 856.56 | 1007.03 |

**Supplement 2.** Contd.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 161 | NUA 238 | 42.00 | 36.50 | 96.75 | 98.25 | 2.75 | 2.50 | 4.00 | 1.75 | 2.50 | 3.00 | 1.00 | 1.25 | 927.19 | 983.20 |
| 162 | NUA 239 | 41.75 | 39.25 | 97.50 | 93.75 | 2.50 | 2.00 | 4.00 | 1.75 | 2.75 | 2.75 | 1.00 | 2.00 | 1817.11 | 945.23 |
| 163 | NUA 240 | 45.00 | 37.25 | 98.25 | 97.50 | 2.75 | 2.50 | 4.25 | 1.25 | 3.00 | 2.25 | 1.00 | 2.00 | 1368.98 | 1537.89 |
| 164 | NUA 244 | 45.25 | 40.25 | 98.75 | 97.25 | 2.75 | 3.00 | 5.00 | 2.50 | 2.25 | 3.00 | 1.00 | 1.00 | 857.27 | 1018.59 |
| 165 | NUA 245 | 41.50 | 37.25 | 97.50 | 96.50 | 2.50 | 2.00 | 3.50 | 1.50 | 3.25 | 2.50 | 1.00 | 1.50 | 1267.11 | 1239.30 |
| 166 | NUA 256 | 43.00 | 39.00 | 101.50 | 100.00 | 2.25 | 2.00 | 4.75 | 2.00 | 3.00 | 2.75 | 1.00 | 1.50 | 1150.78 | 975.08 |
| 167 | NUA 257 | 40.75 | 35.75 | 98.25 | 97.75 | 2.75 | 2.00 | 3.25 | 1.50 | 2.75 | 2.25 | 1.00 | 1.75 | 1244.53 | 696.72 |
| 168 | NUA 272 | 48.00 | 41.25 | 98.25 | 99.25 | 2.25 | 1.50 | 2.75 | 1.25 | 3.50 | 3.50 | 1.00 | 1.50 | 674.14 | 731.56 |
| 169 | NUA 273 | 42.75 | 37.50 | 96.25 | 98.25 | 2.25 | 2.00 | 3.50 | 1.50 | 3.00 | 1.75 | 1.00 | 1.25 | 855.70 | 867.97 |
| 170 | NUA 30 | 39.75 | 36.50 | 97.75 | 99.50 | 2.50 | 2.25 | 4.50 | 2.50 | 2.25 | 1.75 | 1.00 | 1.50 | 670.62 | 1165.31 |
| 171 | NUA 31 | 42.50 | 36.00 | 96.50 | 98.50 | 2.50 | 2.00 | 3.25 | 1.75 | 2.75 | 2.50 | 1.00 | 1.50 | 1379.69 | 1217.89 |
| 172 | NUA 39 | 45.25 | 39.75 | 97.25 | 98.00 | 2.00 | 1.75 | 4.25 | 2.25 | 3.25 | 2.50 | 1.00 | 4.00 | 1507.66 | 649.84 |
| 173 | NUA 40 | 42.00 | 38.75 | 102.00 | 96.75 | 2.00 | 2.00 | 4.75 | 1.25 | 2.50 | 2.00 | 1.00 | 2.00 | 1108.36 | 960.62 |
| 174 | NUA 48 | 46.00 | 41.75 | 99.50 | 95.00 | 2.00 | 2.25 | 4.75 | 2.50 | 2.25 | 4.00 | 1.00 | 1.25 | 1036.64 | 1223.73 |
| 175 | NUA 57 | 46.75 | 40.25 | 98.00 | 96.25 | 1.75 | 2.00 | 3.00 | 1.50 | 3.25 | 3.00 | 1.25 | 1.50 | 758.44 | 788.05 |
| 176 | NUA 59 | 45.75 | 40.75 | 102.75 | 103.75 | 2.25 | 2.50 | 2.75 | 2.00 | 3.50 | 2.50 | 1.25 | 2.75 | 1053.28 | 1722.67 |
| 177 | NUA 64 | 43.75 | 39.25 | 98.75 | 98.25 | 2.00 | 2.00 | 4.00 | 1.50 | 3.00 | 2.50 | 1.00 | 1.25 | 1262.19 | 964.14 |
| 178 | NUA 66 | 42.75 | 38.25 | 97.75 | 100.75 | 2.25 | 1.75 | 3.00 | 1.00 | 3.25 | 2.50 | 1.00 | 1.00 | 1205.23 | 975.86 |
| 179 | NUA 67 | 46.75 | 41.25 | 98.50 | 98.00 | 2.25 | 2.00 | 3.75 | 2.75 | 2.50 | 1.50 | 1.00 | 1.50 | 1127.11 | 880.00 |
| 180 | NUA 79 | 39.50 | 34.75 | 96.50 | 99.25 | 2.25 | 1.75 | 4.50 | 1.75 | 2.75 | 2.75 | 1.00 | 1.75 | 1195.00 | 773.28 |
| 181 | NUA 9 | 43.50 | 38.50 | 99.25 | 99.25 | 2.75 | 2.25 | 3.75 | 1.50 | 2.50 | 2.25 | 1.00 | 1.00 | 1268.83 | 1055.23 |
| 182 | PAN 72 | 45.25 | 40.75 | 99.00 | 98.00 | 2.75 | 1.25 | 1.00 | 1.00 | 1.75 | 2.50 | 1.00 | 1.00 | 1505.00 | 932.19 |
| 183 | PI 207262 | 43.50 | 36.25 | 96.25 | 98.25 | 3.25 | 1.75 | 3.25 | 4.25 | 1.25 | 3.00 | 1.50 | 2.00 | 806.56 | 920.70 |
| 184 | R.K. MICHIGA | 35.50 | 35.00 | 95.25 | 95.50 | 3.75 | 4.00 | 4.25 | 1.00 | 1.00 | 3.25 | 1.00 | 2.50 | 855.16 | 982.62 |
| 185 | RANJONOMBY | 48.00 | 39.50 | 102.75 | 101.00 | 1.50 | 1.00 | 2.50 | 1.50 | 3.50 | 3.00 | 1.00 | 1.00 | 1933.36 | 1425.61 |
| 186 | RAZ 36 | 47.25 | 39.00 | 100.25 | 100.00 | 2.25 | 2.00 | 3.00 | 1.25 | 3.25 | 1.25 | 1.00 | 1.00 | 1403.20 | 824.53 |
| 187 | RAZ 44 | 49.50 | 44.25 | 103.00 | 98.25 | 2.00 | 1.75 | 3.00 | 1.00 | 2.75 | 1.50 | 1.00 | 1.00 | 1880.00 | 1359.45 |
| 188 | RRN 47 | 47.50 | 42.50 | 99.00 | 99.75 | 2.25 | 1.75 | 2.00 | 1.00 | 1.00 | 1.50 | 1.00 | 1.00 | 2062.89 | 906.25 |
| 189 | RRN 48 | 45.00 | 37.50 | 101.00 | 99.75 | 3.25 | 2.00 | 1.75 | 1.00 | 1.00 | 2.25 | 1.00 | 2.00 | 2168.36 | 633.05 |
| 190 | RWR 1059 | 45.75 | 40.75 | 102.25 | 103.00 | 2.75 | 1.75 | 2.75 | 1.00 | 1.25 | 2.75 | 1.00 | 1.00 | 1899.37 | 1215.47 |
| 191 | RWR 2075 | 41.50 | 38.25 | 99.25 | 100.50 | 3.00 | 2.00 | 4.50 | 2.75 | 1.75 | 2.25 | 2.25 | 1.25 | 961.17 | 453.28 |
| 192 | SAB 662 | 47.25 | 42.00 | 98.00 | 98.75 | 3.25 | 1.75 | 3.25 | 2.25 | 2.00 | 1.75 | 1.00 | 1.00 | 1029.06 | 757.11 |
| 193 | SELIAN 05 | 43.00 | 39.00 | 95.75 | 93.00 | 3.00 | 1.00 | 3.25 | 1.50 | 1.00 | 1.50 | 1.00 | 1.00 | 1160.67 | 1181.97 |
| 194 | SM 133 | 44.00 | 41.25 | 99.50 | 96.75 | 2.50 | 1.00 | 1.25 | 1.00 | 3.25 | 2.25 | 1.00 | 1.25 | 2112.89 | 711.17 |
| 195 | SWP 09 | 39.00 | 34.00 | 96.00 | 97.50 | 2.25 | 2.50 | 5.25 | 1.75 | 2.75 | 2.50 | 1.00 | 1.25 | 547.89 | 1367.11 |
| 196 | SWP 10 | 46.75 | 40.25 | 100.75 | 100.50 | 2.25 | 1.75 | 1.75 | 1.00 | 3.00 | 1.75 | 1.00 | 1.25 | 1567.34 | 774.61 |
| 197 | SWP 12 | 45.75 | 39.50 | 98.00 | 96.50 | 2.25 | 1.00 | 1.50 | 1.50 | 3.75 | 2.75 | 1.00 | 1.00 | 1616.72 | 605.16 |

**Supplement 2.** Contd.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 198 | TU | 45.00 | 39.50 | 98.50 | 100.75 | 2.50 | 1.25 | 3.00 | 1.50 | 1.25 | 2.00 | 1.00 | 1.50 | 1121.72 | 1432.42 |
| 199 | VAX 1 | 43.00 | 36.00 | 100.00 | 100.50 | 3.50 | 2.00 | 3.00 | 1.50 | 1.50 | 2.75 | 1.50 | 1.75 | 1953.67 | 1139.45 |
| 200 | VAX 2 | 47.50 | 39.50 | 100.50 | 99.50 | 3.00 | 1.00 | 2.75 | 1.25 | 1.25 | 2.50 | 1.25 | 1.25 | 1445.55 | 1446.64 |
| 201 | ZABR 16573-78F22 | 46.75 | 40.50 | 100.50 | 99.75 | 1.75 | 2.00 | 1.25 | 1.00 | 2.75 | 1.50 | 1.00 | 1.00 | 1236.87 | 902.66 |
| 202 | ZABR 16574-46F22 | 45.50 | 38.75 | 99.25 | 98.50 | 3.25 | 2.25 | 3.75 | 2.50 | 2.50 | 1.75 | 1.00 | 1.25 | 879.53 | 940.86 |
| 203 | ZABR 16575-17F22 | 45.75 | 41.00 | 90.75 | 89.25 | 2.00 | 1.25 | 3.00 | 1.75 | 2.25 | 2.00 | 1.00 | 1.00 | 1862.11 | 1033.05 |
| 204 | ZABR 16575-24F22 | 46.75 | 44.25 | 100.50 | 99.50 | 1.75 | 1.50 | 2.25 | 1.00 | 3.00 | 1.75 | 1.00 | 1.00 | 1802.73 | 659.22 |
| 205 | ZABR 16575-39F22 | 47.75 | 41.75 | 99.50 | 99.50 | 2.50 | 1.50 | 3.00 | 2.00 | 2.50 | 2.00 | 1.00 | 1.00 | 1905.47 | 600.56 |
| 206 | ZABR 16575-51F22 | 49.50 | 40.50 | 102.25 | 102.50 | 1.50 | 1.25 | 2.50 | 1.50 | 3.25 | 2.00 | 1.00 | 1.00 | 1050.23 | 873.67 |
| 207 | ZABR 16575-52F22 | 45.50 | 38.25 | 101.25 | 101.00 | 2.00 | 2.25 | 2.25 | 2.00 | 2.75 | 3.00 | 1.00 | 2.00 | 1118.20 | 1100.48 |
| 208 | ZABR 16575-60F22 | 42.25 | 36.25 | 96.75 | 101.25 | 2.25 | 2.25 | 2.50 | 1.25 | 2.50 | 1.25 | 1.00 | 1.25 | 727.42 | 856.58 |
| 209 | ZABR 16575-86F22 | 48.00 | 42.25 | 100.50 | 101.00 | 2.25 | 1.25 | 2.25 | 1.25 | 2.50 | 2.25 | 1.00 | 1.00 | 1573.05 | 995.08 |
| 210 | ZABR 16576-11F22 | 47.75 | 42.00 | 102.75 | 99.25 | 1.50 | 1.75 | 2.00 | 2.75 | 2.00 | 1.75 | 1.25 | 1.00 | 1214.69 | 724.77 |
| 211 | ZABR 16577-51F22 | 45.00 | 42.50 | 99.25 | 98.25 | 2.25 | 2.50 | 2.00 | 1.25 | 2.50 | 2.50 | 1.00 | 1.50 | 1346.17 | 730.70 |
| | Mean | 44.50 | 39.16 | 99.45 | 98.53 | 2.75 | 1.95 | 2.80 | 1.58 | 2.33 | 2.28 | 1.19 | 1.45 | 1298.07 | 1005.00 |
| | CV (%) | | 7.80 | | 6.30 | | 33.60 | | 44.30 | | 35.60 | | 45.90 | | 42.00 |
| | SGE (5%) | | ns | | ns | | <0.001 | | <0.001 | | <0.001 | | <0.001 | | <0.001 |

DFF: Days to 50% flowering; MD: days to maturity; ALS: Angular leaf spot; PM: powdery mildew; CBB: Common bacterial blight; BCMV: Bean common mosaic virus; CV: Coefficient variation; SGE: Significant effects; ns: Not significant.