

Original Research Article

Effect of Plant Density on Growth and Yield of Maize [*Zea mays* (L.)] Hybrids at Luyengo, Middleveld of Eswatini

ABSTRACT

Maize is staple food and the most cultivated crop in Eswatini. However, its yield is very low partly due to use of non-optimum plant density for different maturity group maize varieties. Thus, an experiment was conducted at Luyengo, Middleveld of Eswatini during the 2018/2019 cropping season. The experiment consisted of factorial combinations of two varieties [SC 403 (early maturing) and PAN 53 (medium maturing)] and three plant densities (44444 plants/ha, 50000 plants/ha, 57143 plants/ha) in randomised complete block design in three replications. Results showed that medium maturing maize variety PAN 53 had higher leaf area, leaf area index, plant height, cob height (139.4 cm), days to 90% anthesis (69 days), dry biomass, thousand kernels mass (374.0 g), grain yield (43.1 t/ha), and stover mass (59.8 t/ha) than the early maturing variety SC 403. With respect to the effect of plant density, as the plant density increased from 44444 to 57143 plants/ha, leaf area, dry biomass at V12 and R5 growth stages, number of cobs per plant, grain yield, stover mass, and thousand kernels mass (g) were decreased while the leaf area index was increased. The interaction effects of variety and plant density were not significant on all the parameters recorded. Thus, it can be concluded that medium maturing variety PAN 53 and plant density of 44444 plants/ha (90 cm × 25 cm) are best options to maximum productivity of maize in the study area. However, the experiment has to be repeated with inclusion of more varieties and densities to reach at more conclusive recommendation.

Keywords: Maize hybrids, PAN 53, plant density, SC 403, yield

27 1. INTRODUCTION

28 Maize is the third most important cereal crop after wheat and rice in the world in terms of area
 29 and production [1]. In Eswatini, maize is the staple food and the most cultivated crop in the
 30 country. It is mainly grown by farmers of rural households in the communal Swazi Nation Land
 31 (SNL) and constitutes 95% of the country's cereal production. Yields vary among the four agro-
 32 climatic zones in Eswatini, with the highest yields obtained in the Highveld (1.55-4.90 t/ha) and
 33 moist Middleveld (1.21- 4.20 t/ha) [2]. However, the maize grain yield obtained in Eswatini is
 34 very low as compared to the world average (5.75 t/ha) and southern Africa average (5.786 t/ha)
 35 [3]. The major reasons for low yield of maize in Eswatini are: erratic rainfall associated with
 36 climate variability, fall armyworm infestation, soil acidity and associated phosphorus deficiency,
 37 and use of non-optimum agronomic practices.

Comment [M1]: The reference since 2012
It is better to cite by new reference

Comment [M2]: The same the reference
since 2014
Now 2019

38
 39 Plant density is one of the most important cultural practices determining grain yield, as well as
 40 other important agronomic attributes of maize. Plant density and arrangement of plants in a unit
 41 area greatly determine resource utilization (such as light, nutrients and water), the rate and extent
 42 of vegetative growth and development of crops, competitive ability of crops with weed, soil
 43 surface evaporation, light interception, lodging and development of an optimum number of
 44 fruiting sites in a crop canopy [4]. Moreover, grain yield of maize is more affected by variations
 45 in plant population density than of other members of the grass family because of its low tillering
 46 ability [5; 6]. Hence, optimum plant density of maize will lead to effective utilization of soil
 47 moisture, nutrients, and sunlight resulting in high yield [7].

Comment [M3]: Use another word

48 However, the optimum plant population of maize depends on several factors such as fertility
 49 status of the soil, soil moisture, varieties, and cultural practices [8]. For instance, Jones [9]
 50 recommended higher densities up to 75,000 plants ha⁻¹ in humid or irrigated areas when
 51 optimum production is required. On the other hand, Chinyere [10] reported that maize plant
 52 population for maximum economic grain yield varied from 30,000 to 90,000 plants per ha.
 53 Hybrids developed in recent years are able to withstand higher plant density levels than older
 54 hybrids [11]. The ability of newer hybrids to tolerate increased crowding stress can be attributed
 55 to lower lodging frequencies, higher N use efficiency [12], higher leaf photosynthesis rates, and
 56 more efficient canopy photosynthesis and stomatal conductance during water stress [13]. These
 57 variations in recommended density of maize with variations in soil type, climate and varieties,
 58 indicate the need to develop location and variety specific recommendation of plant density.

59 However, in Eswatini, maize spacing recommendation of 44,444 plants ha⁻¹ (90 cm×25 cm) has
 60 been used since long time [14], without taking into account the numerous morphological and
 61 maturity differences that exist among maize varieties as well as the existence of soil and climatic
 62 differences.

63 Thus, the objectives of this study were to determine the effects of plant density on growth, yield
 64 components and yield of maize hybrids; and to identify the plant density that maximises the
 65 productivity of different maturity group maize hybrids in the Middleveld of Eswatini.

Comment [M4]: What do you mean?

66

67 2. MATERIALS AND METHODS

68 2.1 Description of Study Site

69 The experiment was carried out at the University of Eswatini, Faculty of Agriculture at Luyengo.
70 Luyengo is located in Middleveld agro-ecology at 26.34° S and 31.12° E at an altitude of 750m
71 above sea level, and the mean annual temperature is 18°C and annual rainfall is between 800mm
72 to 1000mm. The soil type is an *Oxisol* of the Malkerns soil series.

Comment [M5]: Area

73 2.2 Treatments and Experimental Design

74 The experiment consisted of factorial combinations of two varieties [SC 403 (early maturing)
75 and PAN 53 (medium maturing)] and three plant densities [44444 plants/ha (90 cm × 25 cm),
76 50000 plants/ha (80 cm×25 cm), 57143 plants/ha (70 cm × 25 cm)] in randomised complete
77 block design in three replications. The design of the experiment was a randomised complete
78 block design (RCBD) in a factorial arrangement. The size of each plot was 4 rows × 0.9 m × 4 m
79 (14.4 m²) for 90 cm row spacing, 4 rows × 0.8 m × 4 m (12.8 m²) for 80 cm row spacing, and 4
80 rows × 0.7 m × 4 m (11.2 m²) for 70 cm row spacing.

Comment [M6]: Cite the previous studies that consistent with this experiment.

82 2.3 Experimental Field Management

83 The experimental field was ploughed and disked to a fine tilth with tractor and the plots were
84 leveled manually. According to the design, a field layout was made and each treatment was
85 assigned randomly to the experimental units within a block. After seed beds were leveled, rows
86 were made and then maize varieties were planted at the rate of one seed per hill on the 22nd
87 November 2018. Compound fertiliser 2:3:2 (22), consisting of 6.3% N, 9.4% P and 6.3% K was
88 applied as basal dressing at the rate 300 kg/ha. Gap filling was done on the 8th of December
89 2018, a week after first emergence. Limestone ammonium nitrate (LAN) containing 28%
90 nitrogen was side dressed at the rate of 100 kg/ha to all treatments at knee height growth stage of
91 maize. Weeding was carried out manually as required.

Comment [M7]: Levelled

92 2.4 Data Collected

93 Plant height, leaf area index and aboveground dry biomass were measured at three growth stages,
94 *i.e.* V6 (when the collar of the sixth leaf was visible), V12 (when the collar of the 12th leaf was
95 visible) and R5 (when cobs showed a dark red colour) from randomly taken three plants per plot
96 using a 5m tape and the average of the three plants was recorded. Leaf area was determined by
97 measuring the length and maximum width of all the leaves in three plants per plot. Then the leaf
98 area per plant was calculated using the formula: leaf area = average leaf length × average leaf
99 width × 0.75 × average number of leaves per plant as described by Dwyer and Stewart [15].
100 Leaf area index was calculated using the ratio of leaf area per plant over ground area occupied by
101 the plant, *i.e.* 2250 cm² for 90 cm × 25 cm spacing, 2000 cm² for 80 cm × 25 cm spacing, and
102 1750 cm² for 70 cm × 25 cm spacing.

Comment [M8]: Color

103 The aboveground dry biomass weight was determined from sample of three plants per plot after
104 oven drying to constant weight and the values were converted to t/ha. Days to 90% anthesis was
105 recorded as number of days from planting to the period when 90% of the plants in each plot
106 produced tassel with visual observation.

107 Number of cobs per plant was determined by dividing the number of cobs per plot by the number
108 plants per plot. Thousand kernels mass (g) was determined by weighting 1000 randomly taken
109 sun dried kernels from bulk of threshed kernels from each plot area and then the mass was

110 adjusted to 12.5% moisture level. The stover mass was determined by weighing the aboveground
 111 biomass per plot area at harvest after sun drying for five days and it was expressed in t/ha. The
 112 grain yield (t/ha) was determined by weighed the grain yield using a sensitive balance after
 113 shelling the sundried aboveground biomass and the grain yield was adjusted to 12.5% moisture
 114 content. Finally, the harvest index was calculated as the ratio of grain yield to the total
 115 aboveground dry biomass yield per plot.

116

117 2.5 Data Analysis

118 Data collected were subjected to analysis of variance by using GenStat statistical software 18th
 119 edition [16]. The mean separation was made using the Least Significance Difference (LSD) test
 120 at 5% level of significance.

121

122 3. RESULTS

123 3.1 Leaf Area and Leaf Area index

124 There was no significant difference between the varieties in leaf area and leaf area index.
 125 However, medium maturing maize variety PAN 53 had higher leaf area and leaf area index at V6
 126 and V12 growth stages (Table 1). On the other hand, the effect of plant density was significant
 127 ($P < 0.05$) on the leaf area at V12 and R5 growth stages and on leaf area index at R5 growth stage.
 128 At all maize growth stages, the leaf areas were decreased while the leaf area indices were
 129 increased with increasing plant density from 44444 to 57143 plants/ha (Table 1). The interaction
 130 effects of varieties and plant density were not significant on leaf area and leaf area index of
 131 maize.

132

133 Table 1. Main effects of variety and plant density on leaf area per plant and leaf area index (LAI)
 134 of maize at different growth stages

Treatment	Leaf area at V6 (cm ²)	Leaf area at V12 (cm ²)	Leaf area at R5 (cm ²)	LAI at V6	LAI at V12	LAI at R5
Variety						
PAN 53	6924	7317	8195	3.49	3.67	4.11
SC 403	6656	6631	8382	3.33	3.32	4.22
LSD (0.05)	ns	ns	ns	ns	ns	ns
Plant density (ha ⁻¹)						
44444	7200	7593a	8898a	3.20	3.37	3.95b
50000	6818	7036ab	829ab	3.41	3.52	4.15a
57143	6353	6294b	7670b	3.63	3.60	4.38a
LSD (0.05)	ns	1087.6	668.1	ns	ns	0.35

135 *ns* = non-significant at $P = 0.05$; Means in columns followed by different letters are significantly different to each
 136 other at $P = 0.05$ according to Least Significance Difference (LSD) test.

137

138

Comment [M9]: Your results consistent with who?

139 3.2 Plant Height and Cob Height

140 Varieties showed significant ($P < 0.05$) difference in plant height at V12 growth stage, while the
 141 differences in plant height at V12 and R5 growth stages and cob height were not significant.
 142 Variety PAN 53 had higher plant height than variety SC 403 at all the growth stages and higher
 143 cob height (139.4 cm) (Table 2). The effect of plant density also was not significant on plant
 144 height at all the growth stages and on cob height. The plant height at V6 showed increasing trend
 145 with increasing plant density (Table 2). The interaction effects of variety and plant density were
 146 not significant on plant height and cob height of maize.

Comment [M10]: Your results consistent or conflict with who?

147

148 Table 2. Main effects of variety and plant density on plant height and cob height of maize

149

Treatment	Plant height at V6 (cm)	Plant height at V12 (cm)	Plant height at R5 (cm)	Cob height (cm)
Variety				
PAN 53	52.44	238.1a	240.0	139.4
SC 403	50.33	227.1b	233.4	133.5
LSD (0.05)	ns	8.83	ns	ns
Plant density (ha^{-1})				
44444	50.00	231.1	238.3	140.3
50000	51.50	233.5	237.4	134.3
57143	52.67	233.2	234.5	134.8
LSD (0.05)	ns	ns	ns	ns

150 *ns = non-significant at $P = 0.05$; Means in columns followed by different letters are significantly different to each*
 151 *other at $P = 0.05$ according to Least Significance Difference (LSD) test.*

152

153 3.3 Days to 90% Anthesis and Dry biomass

154 Days to 90% anthesis was not significantly different between the varieties, but variety SC 403
 155 was earlier than variety PAN 53 by four days (Table 2). Though the difference was not
 156 significant, days to anthesis was decreased with increased plant density. On the other hand, there
 157 was significant ($P < 0.05$) difference between maize varieties in dry biomass at V12 and R5
 158 growth stages where variety PAN 53 produced higher biomass than variety SC 403 at all the
 159 three growth stages (Table 3). The effect of plant density was not significant on dry biomass, but
 160 the dry biomass showed decreasing trend as the plant density increased from 44444 to 57143
 161 plants/ha at V12 and R5 growth stages (Table 3). The interaction effects of variety and plant
 162 density were not significant on days to anthesis and dry biomass of maize.

Comment [M11]: Ditto

163

164

165 Table 3. Main effects of variety and plant density on days to 90% anthesis and dry biomass of
166 maize

Treatment	Days to 90% anthesis	Dry biomass at V6 (t/ha)	Dry biomass at V12 (t/ha)	Dry biomass at R5 (t/ha)
Variety				
PAN 53	69.0	6.14	18.13a	37.0a
SC 403	65.0	5.92	15.86b	30.4b
LSD (0.05)	Ns	ns	2.07	4.80
Plant density (ha ⁻¹)				
44444	69.2	6.10	18.43	34.6
50000	67.5	6.72	17.14	33.4
57143	64.3	5.28	15.42	33.1
LSD (0.05)	ns	ns	ns	ns

167 *ns = non-significant at P = 0.05; Means in columns followed by different letters are significantly different to each*
168 *other at P = 0.05 according to Least Significance Difference (LSD) test.*

169

170 3.4 Yield Components and Yield

171 There was significant (P <0.05) difference between the varieties for thousand kernels mass,
172 while there were no significant difference between the varieties on number of cobs per plant,
173 grain yield, stover mass and harvest index. However, variety PAN 53 had higher grain yield
174 (43.1 t/ha), Stover mass (59.8 t/ha), and thousand kernels weight (374.0 g) while variety SC 403
175 had higher harvest index (0.464) (Table 4). The effect of plant density was not significant on
176 yield components and yield of maize, but number of cobs per plant, grain yield, stover mass, and
177 thousand kernels mass (g) showed decreasing trend as the plant density increased from 44444 to
178 57143 plants per ha (Table 4). The interaction effects of variety and plant density were not
179 significant on the yield components and yield of maize.

Comment [M12]: S

Comment [M13]: S

180 Table 4. Main effects of variety and plant density on yield components and yield of maize

Treatment	No. of cobs per plant	1000 kernels mass (g)	Grain yield (t/ha)	Stover mass (t/ha)	Harvest index
Varieties					
PAN 53	1.040	374.0a	43.1	59.8	0.436
SC 403	1.040	335.7b	33.5	45.9	0.464
LSD (0.05)	ns	34.71	ns	ns	ns
Plant density (ha ⁻¹)					
44444	1.06	381.2	43.8	70.6	0.398
50000	1.03	347.8	39.1	52.1	0.471
57143	1.03	335.6	32.1	35.8	0.481
LSD (0.05)	ns	ns	ns	ns	ns

181 *ns = non-significant at P = 0.05; Means in columns followed by different letters are significantly different to each*
182 *other at P = 0.05 according to Least Significance Difference (LSD) test.*

183

184

185 4. DISCUSSION

186 4.1 Leaf Area and Leaf Area Index

187 Variety PAN 53 had higher leaf area and leaf area index at V6 and V12 growth stages (Table 1)
188 owing to genetic differences in number, length and width of leaves it produced. In line with this
189 result, Ahmad et al. [17] reported the highest leaf area index (5.82) from variety Pioneer-30D55,
190 while the lowest leaf area index (5.55) was obtained from variety pioneer-3012 and attributed
191 this to less number of leaves per plant and less leaf width.

192 At all maize growth stages, the leaf area were decreased while the leaf area indices were
193 increased with increasing plant density from 44444 to 57143 plants/ha (Table 1). The reduction
194 in leaf area with higher plant density might be due to high competition for assimilates at higher
195 plant density, hence less average leaf area per plant. Increasing plant density could reduce leaf
196 area due to the accelerated leaf senescence, increased shading of leaves, and reduced net
197 assimilation of individual plants. In agreement with this result, Sangakkara et al. [18] reported
198 that the leaf area per plant tended to decline with increasing plant density in maize. Similarly,
199 Imran *et al.* [19] reported that increasing plant density from 65000 to 95000 plants ha⁻¹ decreased
200 the leaf area per plant from 2585 cm² to 2316 cm² in maize linearly and significantly. On the
201 other hand, the increased LAI at higher plant density could be on account of more area occupied
202 by green canopy of plants per unit area. The general trend is that increasing plant density
203 increases leaf area index on account of more number of plants per unit area. Williams [20] also
204 reported that one of the ways of increasing leaf area index is to increase plant density. In line
205 with this result, Abuzar et al. [6] obtained LAI of 2.77 at plant population of 120,000 plants ha⁻¹
206 while the lowest LAI (1.21) was obtained with lower plant population density of 40,000 plants
207 ha⁻¹. Dinh et al. [21] also reported that increasing plant density from 57000 to 84000 plants ha⁻¹
208 increased the leaf area index from 3.52 to 4.67 in maize.

209

210 4.2 Plant Height and Cob Height

211 Variety PAN 53 had higher plant height and higher cob height (Table 2). The differences in plant
212 height and cob height observed between the varieties might be attributed to differences in genetic
213 characteristics of the individual varieties, including height of the varieties. In conformity with
214 this result, many authors [e.g, 22; 23; 24] reported significant plant height differences among
215 maize cultivars. For instance, Azam et al. [22] reported the tallest height (145 cm) for variety
216 Cargill 707 and the shortest height (134 cm) for variety Baber. Karasu [24] also reported
217 significant difference in ear height of maize cultivars where the highest ear height (144.1 cm)
218 was recorded from variety LG 2687 and the lowest ear height (131.5 cm) was obtained for
219 variety GH2547.

220

221 The plant height at V6 showed increasing trend with increasing plant density (Table 2). The
222 increase in plant height with the increase in plant density might be due to the increase in the
223 inter-plant competition for light and the disruption of the balance of growth regulators. The
224 decrease in light penetration into middle and lower layers of canopy decreases auxin
225 decomposition and thus, plant height increases. In consistence with this result, Zamir et al. [25]
226 reported that plant height was increased significantly from 209 cm to 221 cm as the plant
227 population increased from 55556 plants ha⁻¹ to 111111 plants ha⁻¹. Adeniyani [26] also reported

228 that when the plant density was increased from 53000 plant ha⁻¹ to 106 000 plant ha⁻¹, the plant
 229 height was increased significantly from 137.6 cm to 210.8 cm, respectively.

230

231 **4.3 Days to 90% Anthesis and Dry biomass**

232 Variety SC 403 was earlier than variety PAN 53 (Table 2). This might be due to the genetic
 233 variation among the varieties where early maturing varieties require less heat units to reach
 234 anthesis while late maturing varieties exhibit extended vegetative period [27].

235 Days to anthesis was decreased with increased plant density. The earliest anthesis observed in
 236 the highest plant density might be due to intra-specific competition for soil nutrients, water and
 237 sunlight among the plants which ultimately triggers the plants to early reproductive phase. In
 238 agreement with this result, Nwokuwu [28] reported that the lowest plant density of 20,000 plants
 239 ha⁻¹ took more days to tasseling (69.89) while the earliest tasseling (67.35 days) was observed in
 240 the highest plant densities of 80,000 plant ha⁻¹. In contrast to this result, Tokatlis and Koutroubas
 241 [29] reported that the time from planting to silking increased from 84 to 95 days as density of
 242 maize increased from five to 20 plants m⁻². Similarly, Mohammad *et al.* [30] reported that with
 243 increasing plant density from 57000 plant ha⁻¹ to 99000 plant ha⁻¹, the number of days to 50%
 244 silking was delayed in four days.

Comment [M14]: Spelling

245

246 Variety PAN 53 produced higher biomass than variety SC 403 at all the three growth stages
 247 (Table 3). This result was expected as medium maturing variety PAN 53 had more leaf area and
 248 height than early maturing variety SC 403 resulting in more photosynthesis to accumulate more
 249 dry matter. In line with this result, Aziz *et al.* [31] obtained the highest aboveground dry biomass
 250 yield (21.54 t ha⁻¹) for late maturing maize cultivar Ehsan, while the lowest aboveground dry
 251 biomass yield (16.83 t ha⁻¹) was obtained from early maturing cultivar Pahari.

252

253 The dry biomass showed decreasing trend with increased plant density at V12 and R5 growth
 254 stages (Table 3) possibly due to increased inter-plant competition for growth resources like light,
 255 soil moisture and nutrients. Similarly, Asea *et al.* [32] revealed that plant populations that are
 256 higher than the optimum will lead to competition among the maize plants resulting into thin
 257 plants that will give low yield. In contrast to this result, Ayman and Samier [33] reported the
 258 highest dry biomass of 28914 kg ha⁻¹ at the highest plant density of 57124 plants of ha⁻¹.

Comment [M15]: Spelling

259

260 **4.4 Yield Components and Yield**

261 Variety PAN 53 had higher thousand kernels mass (374.0 g), higher grain yield (43.1 t/ha), and
 262 higher stover mass (59.8 t/ha), while variety SC 403 had higher harvest index (0.464) (Table 4).
 263 Thousand kernels weight is a major yield component that has an essential role in determining the
 264 potential yield of variety [25]. Significantly higher thousand kernels mass for medium maturing
 265 variety PAN 53 might indicate the more efficient conversion of solar radiation and other growth
 266 resources into economic yield due to its long grain filling period. In line with this result,
 267 Moraditochae *et al.* [34] reported that thousand kernels weight is a trait, which is more
 268 dependent on the genetic characteristics of varieties, and it is less affected by environmental
 269 factors. Similarly, Belay [35] obtained significantly higher thousand kernels weight (410.15 g)
 270 for the late maturing maize variety BH-661 as compared to the medium maturing variety BH-
 271 QPY-545 (288.6 g).

272 The higher stover yield and grain yield for variety PAN 53 could be due to its higher height and
273 leaf area as well as its late maturity which created a better chance to utilize more nutrients and
274 more photosynthetic activity, which ultimately resulted in higher biomass production and
275 partitioning to the grain yield. In conformity with this result, Belay [35] also reported the
276 maximum grain yield ($11.09 \text{ t}\cdot\text{ha}^{-1}$) for late maturing maize variety BH-661 than medium
277 maturing maize variety BH-QPY-545 ($9.57 \text{ t}\cdot\text{ha}^{-1}$).

278 Harvest index indicates the physiological efficiency of a plant for changing the total dry matter
279 into economic yield [36]. Higher harvest index (0.46) was recorded for early maturing maize
280 variety SC 403 than the medium maturing variety PAN 53 (0.43) (Table 4). The higher harvest
281 index for the early maturing maize variety could be due to lower leaf area index and plant height
282 that might have reduced the above-ground dry biomass yield. In agreement with this result, Iptas
283 and Acar [37] obtained higher harvest index (41.3%) for early maturing hybrid maize than the
284 mid (40.3%) and late (30.1%) maturities of maize hybrids. Belay [35] also reported the highest
285 harvest index (47%) for medium maturing variety BH-QPY-545 than for the late maturing maize
286 variety BH-661 (36%).

287 The number of cobs per plant, thousand kernels weight (g), grain yield and stover mass showed
288 decreasing trend as the plant density increased from 44444 to 57143 plants per ha (Table 4). The
289 use of high plant densities might have reduced the supply of photosynthates to the growing ear
290 thereby reducing the number of ears per plant. . Similarly, Abuzar et al. [6] reported that the
291 number of ears per plant increased with decreased plant population density where the maximum
292 number of ears plant⁻¹ (1.33) was produced in plant density of 60,000 plants per whereas the
293 lowest number of ears per plant (1.0) was produced from plant density of 140,000 plants per
294 hectare. Zamir et al. [25] also reported that as the plant population increased from 55556 plants
295 ha⁻¹ to 111111 plants ha⁻¹, the number of ears per plant was significantly reduced from 1.42 to
296 1.21 possibly due to more competition for light, aeration and nutrients and consequently enabling
297 the plants in closer spacing undergo less reproductive growth.

298 Lower grain weight in high plant density was possibly due to availability of less photosynthates
299 for grain development on account of high intra-specific competition which resulted in low rate of
300 photosynthesis and high rate of respiration as a result of enhanced mutual shading. In conformity
301 with this result, Ijaz et al. [38]; and Amin and Meyasam [39] reported that as the plant density
302 increased, 1000 grain weight was decreased linearly and significantly. Abuzar *et al.* [6] also
303 reported maximum 1000 kernels weight (350.0 g) at minimum plant density (80000 plants/ha)
304 and the minimum 1000 kernels weight (166.7 g) at the highest plant population (140,000
305 plants/ha). Similarly, Mohammad et al. [30] reported that increasing plant population from
306 45000 plants ha⁻¹ to 65000 plants ha⁻¹ decreased thousand kernels weight and maximum thousand
307 grain weight (315 g) was produced at planting density of 45000 plants ha⁻¹.
308

309 The reduction in stover and grain yields with increased plant density might be that plant
310 populations that are higher than the optimum will lead to competition among the maize plants.
311 This result was in agreement with the study by Abuzar et al. [6] who reported the maximum
312 grain yield ($2.6 \text{ t}\cdot\text{ha}^{-1}$) from 60000 plants ha⁻¹ and the lowest grain yield ($0.8 \text{ t}\cdot\text{ha}^{-1}$) from 140000
313 plants ha⁻¹ of maize. In contrast to this result, Raouf et al. [23] reported that grain yield of maize
314 was increased with increasing density from 80,000-120,000 plants per hectare from 3910 to 4650
315 kg ha⁻¹. Norwood [40] also reported that hybrid maize with higher population density of 60,000

316 plants ha⁻¹ gave higher yield (4.02 t ha⁻¹) than lower population density of 30,000 plants ha⁻¹
 317 (2.69 t ha⁻¹). These differences in response suggest that the optimum plant density depends upon
 318 environmental conditions and the cultivars used.
 319

320 5. CONCLUSION

321

322 Medium maturing maize variety PAN 53 had higher leaf area, leaf area index, plant height, cob
 323 height, thousand kernels mass and grain yield than the early maturing variety SC 403. As the
 324 plant density increased from 44444 to 57143 plants/ha, leaf area, number of cobs per plant,
 325 thousand kernels mass and grain yield were decreased. Thus, it can be concluded that medium
 326 maturing variety PAN 53 and plant density of 44444 plants/ha are best treatments to maximum
 327 the productivity of maize in the study area. However, the experiment has to be repeated over
 328 years with the inclusion of more varieties and densities to make a more reliable recommendation.

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Comment [M16]: Improve and add the recommendations

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