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RESEARCH ARTICLE

Evaluation of *Cicer arietinum* (Chickpea) growth performance and yield in different soil types in Zimbabwe

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ABSTRACT

Chickpea performance under different soil types is still hazy in Zimbabwe. A 3-year study to evaluate growth performance and yield of chickpea under different soils types was done at Department of Research and Specialist Services. Two chickpea cultivars (Kabuli and Desi) and 3 different soil types (Domboshava, Harare, Mazoe soils) were tested in a 2 × 3 factorial pot-experiment laid in completely randomized block design (CRBD) with three replicates. Percentage germination, days to initial flowering and 50% flowering were recorded. Crop growth rate (CGR), leaf area ratio (LAR), total dry matter production (TDMP), grain yield and harvest index (HI) were measured. Data was analyzed for variance using JMP version 11.0 and means were separated by HSD0.05. Desi had significantly ($P<0.05$) lower percentage germination and longer days to flowering than Kabuli in all soils. Kabuli under Mazoe soil had shortest (36) average days to initial flowering and both cultivars took longer (> 60) days to flower under Domboshava soil than other soils. Kabuli had highest CGR, LAR and TDMP at 3, 6, 9 and 12 weeks after planting in Mazoe soil compared to other soils. Kabuli had highest (1.2 t ha-1) grain yield under Harare soil but with significantly ($P<0.05$) the same HI to Mazoe soil. Generally, the chickpea cultivars performed better on Mazoe and Harare soils than Domboshava. Farmers can grow chickpeas in pH >4.9 clay soils and avoid sand soils pH ≤4.9 soils. Nevertheless, further researches to evaluate the chickpea growth performance in more than 3 soil types are required.

INTRODUCTION

Cicer arietinum (chickpea) is an annual legume that belongs to leguminous or Fabaceae family. The crop originated in the South-eastern Turkey and is commonly called garbanzo bean in Asian countries (Gaur et al., 2010). Today the crop has been successfully introduced to the other continents like Oceania, Africa, Europe and America (Madzivhandila et al., 2012). The chickpea is the 3rd largest produced legume internationally after the common sugar bean (*Phaseoulus vulgaris*) and field pea (*Pisum sativum*) (Gaur et al., 2010). Estimated chickpea production quantities are approximately 2.4 million tonnes on the world trade (FAO, 2014). Chickpea is mainly grown in the South East Asia where India is the leading producer with 65%, while in Africa, Ethiopia is the largest producer with 4 % (FAO, 2019). Zimbabwe does not contribute any chickpea on the world market suggesting a knowledge gap on its production. Presently, two types of chickpeas the Desi (microsperma) and the Kabuli (macrosperma) are commonly grown (Bampidis and Christodoulou, 2011). The cultivars have an indeterminate growth habit and their global average grain yield ranges from 0.8 t ha^{-1} to 2 t ha^{-1}. However, in Zimbabwe the grain yield of chickpea is still vague (Maya and Maphosa, 2020).

The chickpea is a multi-purpose crop that can be included in various cropping systems to improve soil fertility as it can fix up to 80% of the atmospheric nitrogen (Madzivhandila et al., 2012). Chickpea has a characteristically deep taproot which can excerpt water from diverse strata of the soil profile therefore has the capability to withstand drought conditions making it ideal in drought prone areas e.g., the natural farming regions III, IV and V in Zimbabwe. The chickpea seed contain about 22% protein, 27% carbohydrates, 3% fat (Jukanti et al., 2012), Lutein 8.2 μg g^{-1}, β-carotene 0.5 μg g^{-1} (Ashokkumar et al., 2014; 2015), folates 405 – 537 μg g^{-100} (Jha et al., 2015), hence an important source of proteins in human diets. The crop can avert the problem of hidden hunger which is prevalent in many developing countries especially in Asia and Africa (Maya and Maphosa, 2020). The above ground biomass of chickpea is an excellent fodder for beef and dairy production (Kumara and Deb, 2014). Again, many chickpea cultivars are very early (< 100 days) mature hence a good relay crop that can utilise soil moisture at the end of the growing season thereby reducing the winter gap. The chickpea can therefore be grown in the most marginalized areas of Zimbabwe though evaluations on the growth performance and productivity in such areas are necessary.

Chickpea favours cool weather so can grow well in winter in the tropics and summer in the temperate environments (Gaur et al., 2010). The crop thrives in temperatures between 21 °C to 29 °C and annual rainfall of about 400 mm to 600 mm (Madzivhandila et al., 2012). Chickpea does well in a wide range of soils but favours well drained sandy and silt loam soils (Fikre et al., 2020). Hence, chickpea can be potentially grown in Zimbabwe since a larger proportion of the soils are derived from the granitic rock and sandy (Garwe et al., 2009).

Chickpea requires fertile, sandy-loam soil with good internal drainage and they do not tolerate water-logged conditions (Azeem et al., 2019). The soil should have good residual soil moisture content but even short periods of flooding can adversely reduce growth and increases susceptibility to root and stem rots. Normal growth and increased productivity of chickpea was observed in soil pH between 6. 0 to 9. 0 (Kumar et al., 2006). This suggest that the chickpea production in Zimbabwe can be challenging since largest (>72%) proportion of soils are granitic sand that are inherently infertile and acidic (pH < 6.0) (Parwada and Chinyama, 2021).

In a study by Kando et al. (2001), chickpea was observed to grow well and yield better in Vertisols than sand soils. Usually, the Vertisols are of high calcium and magnesium content indicating that these elements are very essential for the growth of chickpea (Kassie et al., 2009). In addition, the Vertisols contains high (>0.5%) organic matter (OM) and have high (47 - 65 cmol (kg^{-1})) cation exchange capacity (CEC) (Davies et al., 1999). Soil pH should be below 5 for chickpea production because acidic conditions increase aluminium toxicity which reduce nodulation and nitrogen fixation in chickpea (Gaur et al., 2010). Chickpea is not a heavy feeder and requires 20 to 30 kg N ha^{-1}, 40 to 60 kg P ha^{-1} and 17 to 26 kg K ha^{-1} (Gaur *et al*., 2010). However, most Zimbabwean soils are inherently infertile and acid constituting about 70% of the arable land but >60% of communal farmers located on such soils (Parwada and Chinyama, 2021). Considering that Zimbabwe is agro-based, growing of widely adapted crops such as chickpea can be a panacea to food insecurity among the rural poor. Nevertheless, in Zimbabwe, the growth performance of the *Cicer arietinum* under different soil type has not been fully evaluated.

Chickpea is an orphaned crop in Zimbabwe and in not commonly grown by many farmers hence limited agronomic information about the crop. Its average grain yield is low (< 0.8 t ha^{-1}), suggesting an information gap on its agronomy. They are few chickpea farmers and low hectarage (< 250 ha) compared to other legumes such as soyabeans and common bean. Nevertheless, the chickpea is a potential strategic crop to achieve food security in Zimbabwe especially in the marginalised semi-arid areas since it can tolerant drought. Evaluating of the growth and yield performance of the chickpea will therefore avail more agronomic information of the crop. Assessing the chickpea growth performance and yield in different soil types will add to the production knowledge of the crop. This information will help farmers and lead to increased production levels and hectarage of the chickpea. The increased chickpea productivity among the farmers will enhance their food security. This study was aimed at determining the effects of different soil types on growth performance and growth yield of chickpea in Zimbabwe.

MATERIALS AND METHODOLOGY

Site description

The experiment was conducted at the Department of Research and Specialist Services (RD & SS) which is located 5 km north of the Harare Central Business District, Harare, Zimbabwe. The DR & SS lies in the natural farming region IIa and has a latitude of 17° 41'S longitude 30°32'E. The area experiences follow a unimodal rainfall pattern that starts in October to April. The DR & SS is characterized by two seasons within a year that are hot, wet summers (October to April) and cool dry, winters (May to August). The DR& SS receives an average annual rainfall of 800 mm and winter temperature ranges between 12.3°C to 18°C. Soils in the area are classified as fersiallitic red clays which are deep well drained and derived from epidiorite rock (Nyamapfene, 1983).

Experimental design and treatments

The study was a pot-experiment laid in a 2 × 3 factorial arranged in a complete randomised block design (CRBD) with 3 replicates. Slope was the blocking factor. The experiment was carried in the winter (June to August) seasons of 2019, 2020 and 2021. The factors were chickpea cultivars (Kabuli and Desi) and soil types [(sand and very acidic (pH = 4.9) Domboshava soil, fersiallitic red clays and slightly acidic (pH= 6.4) Harare soil and black clay and slightly acidic (pH= 6.6) Mazoe soil)] to make a total of six treatment combinations (Table 1).

Descriptions of chickpea cultivars used

The Desi is coloured with a thick firm seed coat. The seed colours range from brown to fawn and are generally small and angular with a rough surface and the flowers are pink. The Desi plants show various degrees of anthocyanin pigmentation on their stems (Berger et al., 2011). Desi plants are usually shorter than Kabuli in addition the seeds are 120 mg and wrinkled at the beak (Gaur et al., 2010). Both cultivars take about 120 days to mature and yield 0.8-2 t ha^{-1}. The Kabuli type is white or beige coloured with a ram's head shape, thin seed coat, and smooth seed surface and weighs about 400 mg.

Table 1. Treatment combinations used in the study

Chickpea cultivars	Soil type	Treatment combination	Acronym name
Kabuli type	Soil A (Harare)	Kabuli ×Soil A	HK
	Soil B (Domboshava)	Kabuli× Soil B	DK
	Soil C (Mazoe)	Kabuli × Soil C	MK
Desi type	Soil A(Harare)	Desi× Soil A	HDs
	Soil B (Domboshava	Desi × Soil B	DDs
	Soil C (Mazoe)	Desi × Soil C	MDs

Seed viability test

The seeds were tested for viability before use. The seed viability tests were done in the laboratory at Seed Services Institute at DR & SS, Harare, Zimbabwe at the beginning of winter (April) season each year. The seed viability tests were conducted in the presence of light at 20°C. Briefly, 8 seeds for each variety were planted in moist sand as a germinating substrate. A wooden stake with holes was used to create equidistant holes in the trays and row marking. The seeds were placed in the holes and then covered with moist sand soil levelled to full capacity of the trays. First germination counts were done at 7 days interval up to 21 days. The total number of germinated seeds were counted and recorded. Germination percentage was obtained by dividing the number of seeds that emerged with total number of seeds planted and multiplied then multiply by 100. The average percentage germination Kabuli and Desi during the 3 years were 75 and 46.25 respectively.

Soil sampling and analysis

Soils used were collected in April 2019 from cultivated fields in Domboshava, Harare research station and Mazoe, Zimbabwe. Soil sampling was done on 50 sampling stations and thoroughly mixed to get a 100 kg composite sample per field. The soil was sampled at a uniform depth of 0-30 cm using a graduated auger. Three 50 g subsamples of each soil were sent to the Institute of Soil Chemistry, Department of research and specialist services (DR & SS), Harare, Zimbabwe for characterisation. The bulk soil was stored in a cool and dry store room before use. The soil was analysed for pH, cation exchange capacity (CEC), electron conductivity, soil macronutrient [(Nitrogen (N), Phosphorus (P) and Potassium (K)] and micronutrient [(magnesium (Mg) and calcium (Ca)] content using a procedure described by Okalebo (2000). Primary particle size distribution was analysed according to Parwada and Van Tol (2018).

Experiment preparation and planting

Pots measuring 24.2 cm in diameter and 21.5 cm in height were filled with different soil types from Harare, Domboshava and Mazoe to a volume of 9893.13 cm^3 of soil. A block consisted of 6 plots and each plot had 4 pots. The pots were spaced at 30 × 30 cm so a plot was 3600 cm^2 in size. Compound D (N-7%. P-14%. K-7%) was applied to the plots using a blanket recommendation of 300 kg ha^{-1} at planting. Then the pots were uniformly watered before 24- seeds were sown at a depth of 2.5 cm in all soils per plot according to the design. The seedlings were thinned to 10 × 30 cm spacing rate at four weeks after emergence. The planting was done in June every year.

Data collection

Seed germination rate in the different soil types was determining by measuring percentage emergence at 14 and 21 days after planting. Number of seedlings that emerged at 14 and 21 days after planting were counted and calculated as follows:

$$Percentage\ germination = \frac{emerged\ seedlings\ at\ 7\ days\ after\ planting}{total\ number\ of\ seed\ planted} \times 100$$

Days to initial flowering and 50% flowering by the chickpea cultivars under different soil types were recorded. Crop Growth Rate (CGR) and Total Dry Matter Production (TDMP), leaf area ratio (LAR) was recorded at three weeks interval from planting up to physiological maturity stage. Leaf area estimation was done by measuring the length and width of two randomly selected leaves per plot. Average leaf area of the two leaves was multiplied by a factor of 0.75 and divided by the total dry weight of the whole plant to obtain the Leaf Area Ratio (LAR). The CGR and TDMP were measured by randomly selecting two plants per plot, the plants were uprooted and weighed before being oven-dried at 70°C until a constant weight. Grain yield (t ha^{-1}) and Harvest Index (HI) were determined at harvest stage. The HI was determined by dividing the shelled seed weight by total biological yield per plot and grain yield (**Table 2**). The chickpea growth responses variables that were measured are summarized in Table 2.

Table 2. Growth response variables measured in the study

Response variable	Acronym used	Equation
Crop growth rate	CGR	$(W_2 - W_1)/p(t_2 - t_1)$ $gm^{-2}day^{-1}$
Leaf Area Ratio	LAR	Total leaf area/total plant dry weight ($cm^{-2}g$)
Total dry area matter production	TDMP	TDMP per plot/Area per plot (t ha^{-1})
		Shelled yield/Total biological yield *100
Harvest Index	HI	

W_1 and W_2 are the whole plant dry plant weights at time t_2 -t_1 are and p is the ground area of which *W_1* and *W_2 are leaf weights at t_1 and t_2 respectively.*

Data analysis

The data was tested for normality before analysing effects of the different soil types on the growth performance and yield of the chickpea cultivars. The data was normally distributed hence analysis of variance (ANOVA) was done using JMP version 11.0.0 version. Where there were significant ($P<0.05$) differences, means were separated using the HSD at $P \le 0.05$.

RESULTS

The soil had different values of the measured physical and chemical properties. Domboshava contained highest (94%) sand (fine, medium and coarse) particles and had lowest (4.9) pH compared to the Mazoe and Harare soils (**Table 3**). Mazoe soil had the highest (15%) clay particle and a slightly acidic pH of 6.6. Mazoe soil had highest (8.3 me %) CEC and highest nitrogen content of (15 mg kg^{-1}) compared to the Harare and Domboshava soils. Domboshava had the lowest (6 mg kg^{-1}) nitrogen content, CEC of 3.1 (me %) and E/C of 44.4. The nitrogen content per hectare of soils were 30 kg for Mazoe soil, 22 kg for Harare soil and 12 kg for the Domboshava soil whereas phosphorus content of Harare, Domboshava, and Mazoe soils were 42 kg ha^{-1}, 48 kg ha^{-1} and 18 kg ha^{-1} respectively (**Table 3**).

Table 3. Properties of Harare, Mazoe and Domboshava soils used in the study.

Soil property	Harare	Mazoe	Domboshava
Clay %	13±1.2	15±1.3	5±0.7
Silt%	40±3.3	47±3.4	1±0.2
Fine sand %	22±1.6	26±1.5	20±1.4
Medium sand %	14±1.1	7±1.0	40±2.5
Coarse sand %	11±0.9	4±0.7	34±0.6
pH (CaC12)	6.2±0.5	6.6±0.4	4.9±0.5
Extractable NO_2/NO_3 (mg kg^{-1})	11±1.2	15±1.0	6±0.8
Olsen extractable P (mg kg^{-1})	21±2.1	24±2.3	9±1.5
K (mg kg^{-1})	1.21±0.2	0.84±0.1	0.12±0.01
Ca ($cmol_{(+)}$ kg^{-1})	12.69±1.1	20.90±2.1	5.00±1.0
Mg ($cmol_{(+)}$ kg^{-1})	2.89±0.8	5.47±0.6	0.76±0.11
EX Ca (me %)	1.4±0.6	0.8±0.2	1.0±0.03
EX Mg (me %)	1.7±0.7	1.1±0.02	1.2±0.01
EX Na (me %)	0.09±0.1	0.06±0.01	0.00±0.0
EX K (me %)	0.29±0.1	0.25±0.01	0.22±0.01
TEB (me %)	3.5±1.3	2.3±0.9	2.4±0.8
CEC (me %)	5.8±1.2	8.3±1.3	3.1±0.9
BASE SAT %	60±3.1	27±1.4	79±3.7
E/C (dS/m)	56.3±2.3	66.8±3.0	44.4±2.1
ESP	1.5±0.7	0.7±0.2	0.0±0.00

E/C, electrical conductivity; CEC, cation exchange capacity; ESP, exchangeable sodium percentage; Data are means ± standard error of the means for three replicates.

All the soils indicated salinity characteristics because the neutral soluble salts (E/C >4dS/m) and high proportion of sodium ions (ESP>15) (**Table 3**). Salinity has adverse effects on the growth performance of crops.

Effect of soil type on the chickpea percentage germination and days to flowering

The season had no significant effects on all the measured growth parameters. However, there were significant ($P<0.05$) interaction effects of soil type × chickpea variety on the growth performance of chickpea (**Table 4**). The percentage germination of the chickpea cultivars significantly ($P<0.05$) varied among the soil types and time after planting.

Percentage germination of Kabuli under Mazoe and Harare soils was significantly ($P<0.05$) the same at 14 days after planting. However, on average the percentage germination was highest (29%) on Kabuli under Mazoe soil (MK) and lowest (0%) on Desi in all soils. At 21 days after planting MK had the highest (74 %) percentage germination and Desi had lowest percentage germination in all the soils (**Table 4**).

The days taken to initial flowering were significantly ($P<0.05$) the same on DK and MDs, DDs and HDs. Nevertheless, the average days to initial flowering were significantly ($P<0.05$) shortest (36 days) on MK and longest (67 days) on MDs. Average days to 50% flowering were significantly ($P<0.05$) the same on DK, MDs, DDs, HDs and HK but the shortest (48 days) days to 50% flowering were recorded on MK (**Table 4**).

Effects of variety and soil type on chickpea leaf area ratio at different times after planting

There were significant ($P<0.05$) variations in the effects of variety × soil type × time on the leaf ratio (LAR) of chickpea. Leaf area ratio significantly ($P<0.05$) increased at 3 to 9 weeks after planting. The LAR was maximum at week 9 after planting thereafter declined in all soil types. At 3 weeks after planting, LAR was significantly ($P<0.05$) highest (4 $cm^{-2}g$) under MK and lowest (1 $cm^{-2}g$) on HD. The same trend was also observed at 6 weeks after planting. Week 9 after planting the LAR on DK, HK and MK were significantly ($P<0.05$) the same. Again, the LAR was significantly ($P<0.05$) the same on HDs MDs and DDs at 9 weeks after planting (**Figure 1**). However, highest (11 $cm^{-2}g$) and lowest (6 $cm^{-2}g$) LAR were recorded on MK and HDs respectively. At week 12 after planting, the LAR showed a significant ($P<0.05$) decline from 9. A largest (40%) and smallest (22%) decline in LAR were observed under DK and MK respectively. A sequential descending order the declining of the LAR declining at week 12 after planting was observed to be DK>MDs>DDs>HDs>HK>MK (**Figure 1**).

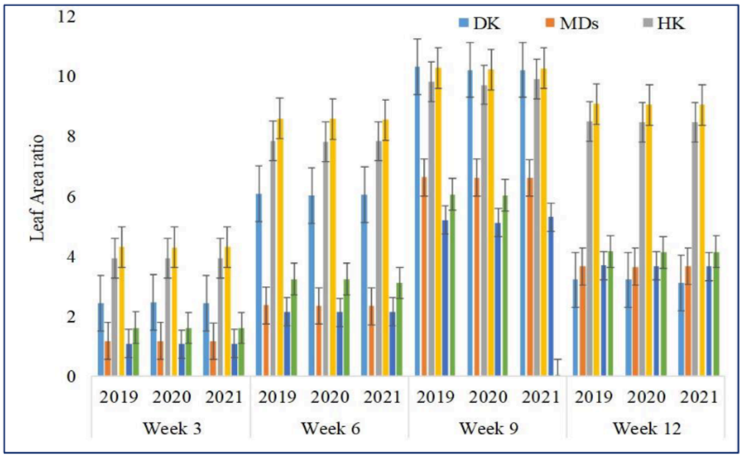

Figure 1. Leaf area ratio at different times after planting in different soil types

Effect of time, soil type and variety on total dry matter production (TDMP)

There were significant (P<0.005) interactive effects of variety (V) × soil type (S) × time after planting (T) on the total dry matter production (TDMP) at different weeks after planting (Table 4.2). The TDMP of the chickpea cultivars varied significantly (P<0.05) with soil type and time after planting (**Table 5**).

The TDMP was significantly (P<0.05) the same on DK, MDs, HK and DS at 3 weeks after planting. Highest (5.62 t ha^{-1}) and lowest (1.78 t ha^{-1}) total dry matter production were also noted in MK and MDs respectively at 3 weeks after planting. At 6 weeks after planting, Kabuli under Mazoe soil recorded the highest (8.23 t ha^{-1}) TDMP while Desi under Domboshava soil had the lowest (3.17 t ha^{-1}) TDMP (Table 5). At 9- and 12-weeks after planting, Kabuli under Domboshava soil had the least (4.01 t ha^{-1}; 3.41 t ha^{-1}) dry matter production respectively. Kabuli under Mazoe soil had the highest total dry matter production both at 9 and 12 weeks after planting, 10.52 t ha^{-1} and 8.63 t ha^{-1} respectively (**Table 5**).

The TDMP under MDs, HK and DDs were significantly (P<0.05) the same at 3 and 9 weeks after planting and significantly the same between MDs and HK at 9 weeks after planting (Table 5). The TDMP was significantly (P<0.05) highest and lowest at week 9 and 3 after planting respectively in all treatments. The TDMP declined as from week 9 to week 12 after planting (**Table 5**).

Effect of chickpea variety × soil type × time after planting on crop growth rate and harvest index (HI)

The crop growth rate (CGR) of the chickpea varied significantly (P<0.05) with soil type and time after planting (Table 6). The harvest index (HI) also varied significantly (P<0.05) among the treatments.

At 3 weeks after planting, the crop growth rate was significantly (P<0.05) highest (2.68 gm^{-2}day^{-1}) under MK and lowest (0.49 gm^{-2}day^{-1}) under DDs. The same trend of CGR was observed at week 6 after planting (Table 6). At 9 weeks after planting, the HK and MK recorded significantly the same CGR. Significantly (P<0.05) similar CGR were also recorded on HDs and MDs at 9 weeks after planting (Table 6). The CGR was significantly (P<0.05) highest and lowest at week 9 and 3 after planting respectively in all treatments (Table 4.6). The CGR showed a general decrease as from week 9 to week 12 after planting (**Table 6**).

At week 12 after planting, highest (7.47 gm^{-2}day^{-1}) and lowest (2.51 gm^{-2}day^{-1}) CGR were recorded under MK and DK respectively. At week 12 after planting, the CGR were lower than week 9 after planting. Largest (40.59%) changes in drop of the CGR at week 12 after planting was noted on HK and lowest (16.61%) decline was observed on DK at 12 weeks after planting (Table 6). Harvest index (HI) was significantly (P<0.05) higher on MK and HK than the rest of the treatment (**Table 6**).

Table 4. Effects of soil type × variety × time on the percentage germination and days to flowering.

Treatment	% germination at 14 days			% germination at 21 days			Days to initial flowering			Days to 50% flowering		
	2019	2020	2021	2019	2020	2021	2019	2020	2021	2021	2020	2021
DK	13^{a}	12^{a}	13^{a}	43^{b}	44^{b}	42^{b}	62^{a}	63^{a}	62^{a}	69^{a}	68^{a}	69^{a}
MDs	0^{b}	0^{b}	0^{b}	5^{c}	6^{c}	5^{c}	67^{a}	66^{a}	67^{a}	69^{a}	69^{a}	69^{a}
DDs	0^{b}	0^{b}	0^{b}	3^{c}	3^{c}	4^{c}	56^{c}	55^{c}	56^{c}	60^{a}	61^{a}	61^{a}
HK	28^{c}	26^{c}	26^{c}	56^{b}	55^{b}	57^{b}	41^{b}	40^{b}	41^{b}	49^{ab}	48^{ab}	47^{ab}
MK	29^{c}	30^{c}	29^{c}	74^{a}	73^{a}	74^{a}	36^{b}	35^{b}	35^{b}	48^{b}	47^{b}	47^{b}
HDs	0^{b}	0^{b}	0^{b}	4^{c}	4^{c}	5^{c}	57^{c}	56^{c}	57^{a}	69^{a}	70^{a}	69^{a}
$HSD_{0.05}$	12.3	11.4	12.2	15.4	15.0	15.4	6.8	6.6	6.8	11.4	11.4	11.3
P-value	0.001	0.002	0.001	0.004	0.004	0.003	0.001	0.001	0.001	0.02	0.01	0.02
CV%	11.7	11.0	11.6	17.3	17.2	17.3	10.9	10.7	10.6	12.4	12.1	12.3
SED	5.7	5.6	5.8	3.8	3.8	3.7	4.9	4.8	4.9	5.1	5.0	5.3

Means followed by the same letter in a column were not significantly different at P<0.05

Table 5. Effect of time, soil type and variety on total dry matter production (TDMP) (t ha^{-1})

Treatment	Time in weeks after planting											
	3			6			9			12		
	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021
DK	1.80^{a}	1.81^{a}	1.81^{a}	3.92^{a}	3.91^{a}	3.90^{a}	4.01^{a}	4.00^{a}	4.02^{a}	3.41^{a}	3.40^{a}	3.39^{a}
MDs	1.77^{a}	1.78^{a}	1.77^{a}	3.74^{a}	3.72^{a}	3.73^{a}	6.33^{b}	6.31^{b}	6.30^{b}	5.34^{b}	5.33^{b}	5.34^{b}
HK	2.69^{a}	2.70^{a}	2.70^{a}	6.52^{b}	6.50^{b}	6.52^{b}	9.10^{c}	9.00^{c}	9.09^{c}	7.02^{c}	7.00^{c}	7.01^{c}
MK	5.61^{b}	5.62^{b}	5.61^{b}	8.23^{c}	8.21^{c}	8.22^{c}	10.52^{c}	10.48^{c}	10.52^{c}	8.63^{d}	8.60^{d}	8.59^{d}
HDs	4.18^{c}	4.19^{c}	4.18^{c}	6.51^{b}	6.52^{b}	6.51^{b}	8.02^{d}	8.00^{d}	8.01^{d}	6.16^{bc}	6.15^{bc}	6.15^{bc}
DDs	1.90^{a}	1.90^{a}	1.89^{a}	3.17^{a}	3.16^{a}	3.17^{a}	4.02^{a}	4.00^{a}	4.01^{a}	3.89^{a}	3.86^{a}	3.85^{a}
$HSD_{0.05}$	1.22	1.23	1.23	0.98	0.97	0.98	1.43	1.42	1.40	1.2	1.3	1.2
P-value	0.002	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.001	0.001	0.002	0.002
CV%	14.9	15.2	15.2	11.67	11.65	11.63	18.23	18.21	18.20	16.01	16.00	16.01
SED	0.63	0.64	0.64	0.38	0.37	0.38	0.56	0.55	0.56	0.73	0.71	0.72

Means followed by the same letter in a column were not significantly different at P<0.05

Table 6. Effect of chickpea variety × soil type × time after planting on crop growth rate and harvest index (HI)

Treatment	Time in weeks after planting												HI		
	3			6			9			12			2019	2020	2021
	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021			
DK	0.81^{a}	0.80^{a}	0.81^{a}	1.87^{a}	1.88^{a}	1.87^{a}	3.01^{a}	3.01^{a}	3.00^{a}	2.51^{a}	2.50^{a}	2.51^{a}	0.38^{a}	0.39^{a}	0.38^{a}
MDs	0.69^{a}	0.68^{a}	0.68^{a}	2.14^{a}	2.12^{a}	2.13^{a}	4.25^{b}	4.23^{b}	4.25^{b}	2.84^{a}	2.83^{a}	2.84^{a}	0.47^{a}	0.46^{a}	0.46^{a}
HK	1.76^{b}	1.75^{b}	0.76^{b}	4.56^{b}	4.55^{b}	4.56^{b}	10.15^{c}	10.14^{c}	10.15^{c}	6.03^{b}	6.00^{b}	6.02^{b}	0.58^{ab}	0.59^{ab}	0.58^{ab}
MK	2.68^{c}	2.64^{c}	2.66^{c}	6.13^{c}	6.10^{c}	6.12^{c}	11.12^{c}	11.12^{c}	11.11^{c}	7.47^{c}	7.46^{c}	7.47^{c}	0.56^{ab}	0.56^{ab}	0.57^{ab}
HDs	0.69^{a}	0.68^{a}	0.69^{a}	1.56^{a}	1.55^{a}	1.56^{a}	4.03^{b}	4.01^{b}	4.02^{b}	2.76^{a}	2.74^{a}	2.75^{a}	0.39^{a}	0.40^{a}	0.40^{a}
DDs	0.49^{a}	0.48^{a}	0.47^{a}	2.17^{a}	2.16^{a}	2.17^{a}	5.86^{d}	5.84^{d}	5.85^{d}	3.09^{a}	3.08^{a}	3.09^{a}	0.39^{a}	0.38^{a}	0.39^{a}
HSD$_{0.05}$	0.59	0.58	0.58	1.32	1.32	1.31	1.10	1.11	1.10	0.98	0.96	0.97	0.19	0.19	0.20
P-value	0.002	0.001	0.001	0.001	0.001	0.001	0.012	0.010	0.012	0.001	0.001	0.001	0.020	0.010	0.010
CV%	17.9	17.8	17.8	13.1	13.0	13.2	15.0	15.1	15.0	12.3	12.1	12.1	13.4	13.6	13.6
SED	0.35	0.34	0.34	0.46	0.45	0.46	0.39	0.38	0.39	0.41	0.40	0.40	0.36	0.38	0.37

Means followed by the same letter in a column were not significantly different at P<0.05

Effects of soil type on chickpea grain yield (t ha^{-1})

The grain yield varied significantly (P<0.05) among the treatments. The grain yield was significantly (P<0.05) the same on DK, MDs, DDs and HDs, and HK and MK (Figure 2). The grain yield was generally higher on the HK and MK than on DK, MDs, DDs and HDs.

The HK and MK had an average yield of (1.2 t ha^{-1}) while the other treatments had average yield less than (0.3 t ha^{-1}) (Figure 2). The grain yield was significantly higher in HK and MK than in the other the treatments (**Figure 2**).

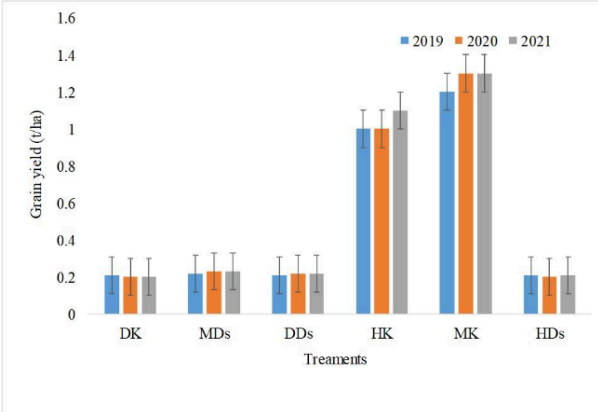

Figure 2. Chickpea grain yield (t ha^{-1}) under different soil types.

DISCUSSION

The percentage germination and days to flowering of the chickpea varied in the different soil types. The percentage germination of Kabuli was high under Harare and Mazoe soils and low in the Domboshava soil. Desi had low emergency and took >7 days to emerge in all the soils (Table 4). The observed variations in germination could be due to the gene × soil type effect. The seed viability of the cultivars was different were Desi had lower viability (46.25%) than Kabuli. However, Kabuli had lowest percentage germination in the Domboshava soil, suggesting that chickpea seed germination is difficult sand and acidic (pH = 4.9) soils (Table 3). These results are to Hossein et al., (2009) who observed a delayed emergency and low (40-60%) legume seed percentage germination under acidic (pH <5.0) soils. Jarawah et al. (2018) also observed lower emergency and seedling performance in pea (*Pisum sativum*) in sand (>60% sand particles) than in less acidic clay soil. Our results are confirming to the need to raise soil pH in acidic soils before planting chickpea seeds in order to increase the germination.

Days to initial and 50% flowering of followed a similar trend to that of seedling percentage germination (Table 4). Plants grown in soils with >20 kg N ha^{-1} (Mazoe and Harare soils) took shorter days to flower than under soil with < 20 kg N ha^{-1} (Domboshava soil) (Table 3). Generally, Desi took more days to flower than the Kabuli in all the soils (Table 4). The differences in days to flowering could be due to genotype × soil type interaction. Soils with pH > 4.9 and high (20 kg N ha^{-1}) nitrogen content resulted to shorter flowering days. This suggest that the soil nutrition was influential on the flowering. Under good soils with adequate nutrients and moisture, that is slightly acidic soils with 20-30 kg N ha^{-1}, the chickpea can flower in >60 days after planting. The Mazoe and Harare soils supplied adequate N and P for the chickpea hence >60 days to initial flowering (Table 4). The results are similar (Wang et al., 2006; Cowie et al., 1996) who also observed reduced number of days taken to flowering in peas under fertile soils.

Crop growth rate (CGR) of chickpea cultivars was different among the soil types. The Kabuli had higher CGR under Mazoe and Harare soils than Domboshava soil. Desi had slower growth rate than Kabuli in all the soil types. The difference in nutrient content of the soils influenced the growth and development of chickpea. Chickpea production is most suitable to well-drained neutral to alkaline soils, from loams to clays. In this study, chickpea grown in soils pH >4.9 had a higher crop growth rate (Table 6). Kassie et al. (2009) observed a similar growth habit of chickpea under less acidic soils. Both Kabuli and Desi had lower crop growth rate in Domboshava soils (pH of 4.9). Soil pH influences the availability and solubility of plant nutrients. The plant growth nutrients like N, P, K could have been unavailable to the chickpea under the acidic Domboshava soil resulting to the low growth rate and TDMP (Tables 5 & 6). The CGR showed a relationship with the Leaf are ratio (LAR). An increase in the LAR resulted to an increase in the CGR. The LAR is a measure of the efficiency with which a plant deploys its photosynthetic resources. Typically, it is increased by low light intensities. The LAR increased with time after planting and started to decrease as from week 9 after planting (Figure 1). Increase in the leaf size resulting to greater light interception and hence increased photosynthesis could have caused high crop growth rate recorded 3 to 6 weeks of planting (Table 6). The declining in the CGR and LAR as from week 9 after planting could be due the increased leaf senescence at that growth stage. Similar trends in the CGR and LAR were noted by Parwada et al., (2020) in baby spinach under different organic manures. In this study, there were significant variations on the LAR under different soil types at 3 and 6 weeks after planting which could have been caused by varying soil nutrition. This reflected significant differences in the nutrient uptake by the chickpea cultivars in different soil types. The Mazoe and Harare soils had more available nutrients compared to the Domboshava soils and this could explain the observed differences in CGR and LAR. In this study, the LAR was gradually increasing from 3 to 6 weeks of planting and peak at 9 weeks thereafter declined in both Kabuli and Desi under different soil types (Figure 1).

Total dry matter production is dependent on crop growth rate. There variations in total dry matter production among the soil types (Table 5). The TDMP of the chickpea cultivars showed a linear increase from week 3 to week 9 after planting thereafter decreased to 12 weeks after planting under different soil types. At week 3 after planting, the plants were at log phase was characterised by slow TDMP since the seedlings were acclimatising to the soil environment. As from 3 to 9 weeks there was rapid production of dry matter due to increased nutrient absorption by the roots and photosynthetic rate as the leaves were large to capture sunlight. This could have led to the photo assimilates being partitioned to the leaves, stems and roots hence the high TDMP observed. The results agree to Gan et al. (2002) who observed highest dry biomass production by chickpea at 8-9 weeks after planting. The decline in the total dry matter production as from 9 to 12 weeks after planting could be due to that the crop had reached its physiological maturity stage.

In general, the HI is the % ratio of economic and biological yield of a crop. The HI varied across the soil types and variety (Table 6). The observed variations in the HI of the chickpea cultivars could be due to different soil nutrient contents. The Harare soil could have supplied adequate growth nutrients compared to other soils which promote high rates of nutrient uptake resulting to high biomass production. There could be nitrogen toxicity under the Mazoe soil (had more than 30 kg N ha^{-1}) (Table 3) that prompted vegetative growth at the expense of reproduction therefore lower HI compare to the Harare soil (Table 6).

Grain yield for legumes is the result of optimal flowering to ensure a comprehensive canopy development and a higher HI. The variations of grain yield in the study could have been instigated by the different soil chemical and physical properties in the different soil types (Table 3). The Desi and Kabuli variety yielded higher in Harare and Mazoe soils than in the Domboshava soils and this could be due that these soils had higher nutrient content and ideal pH (>4.9) for the chickpea growth. Generally, the Kabuli yielded higher than Desi in all soils (Figure 2) and this could be due to the differences in genetic performance. Gaur et al. (2010) also observed that different chickpea cultivars performed differently even under similar soil conditions.

Rasool et al. (2015), stated that yield performance of chickpea is also susceptible to deficiencies in some elements in agricultural soils such as nitrogen, phosphorus and calcium. The same sentiments were observed in this study from the chickpea cultivars under the Domboshava soils. (Table 4). In addition, low yields from the Desi and Kabuli chickpea under Domboshava soil could be because of low soil fertility and hence the necessity to put into practise soil fertility management options. The similar idea was recommended by (Ncube, 2007) in the production of legumes in the semi-arid regions of Zimbabwe. Moreover, Azeem et al., (2019) also revealed that low fertile soil influences biomass and grain yield in mash bean and wheat.

CONCLUSIONS

Different soil properties had different effects on the growth performance and yield of the chickpea. The percentage germination and days to flowering of the chickpea varied among the soil types. Kabuli took shorter days to emerge and flower under slightly acidic pH (>4.9) than in very acidic pH (≤ 4.9) soils. Generally, Desi had lower seedling emergence rate and longer days to flowering than Kabuli cultivars in all the soils. Growth rate, total dry matter production (TDMP) and leaf area ratio (LAR) also differed among the soil types. Higher crop growth rate, TDMP and LAR, grain yield and harvest index were higher under slightly acidic pH (>4.9) than in very acidic pH (≤ 4.9) soils.

Farmers can successfully grow chickpea in soils with properties similar to Mazoe and Harare soils (seedling emergence, growth rate and grain) and avoid sand and acidic soils. Nevertheless, there is need for further studies especially on evaluating the chickpea growth performance in more than 3 soil types and determine the nitrogen fixation rate under these soils.

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COMPETING INTERESTS

The authors declare that they have no competing interests

DATA AVAILABILITY STATEMENT

The raw data used to support the findings of this study are available from the corresponding author upon request.

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