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Enhancement the Productivity of Teosinte, Pearl Millet and Sorghum Crops for Resistance to Common Smut and Downy Mildew Diseases

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TO STUDY correlation and path analysis for yield and its attributing characters ten forage and silage summer forage crops were evaluated at Sakha Agricultural Research Station in (Northern Delta) A.R.C., Egypt, 2020 and 2021 summer seasons. the studied crops were seven summer forage crops (three cuts) and three summer forage crops (only one cut). Highly significant differences were detected among the seven genotypes over the two seasons for plant height, stem diameter, fresh yield, dry yield at the three cuts over two seasons and their total fresh and dry yields. Highly significant differences were found among the three crops for silage fresh, dry yield and its components in the combined analysis. Correlation coefficients were highly significant in positive direction between fresh forage yield cut 1, 2, 3, total fresh yield, dry yield cut 1, 2, 3, total dry yield, plant height cut 1, 2, 3, stem diameter cut 1, 2 and cut 3 implying the effectiveness of these traits in selection for fresh forage yield. In addition, insignificant negative estimates of correlation coefficients observed between fresh forage yield cut 1, 2, 3, total fresh yield, dry yield cut 1,2,3, total dry yield, plant height cut 1,2,3, stem diameter cut 1, 2 and cut 3 and each of fresh leaf stem percent cut 1, 2, 3, LI%, SI and TI% traits, indicating that selection of low LI%, SI and TI% contribute to high estimates of these characters. Highly significant and negative estimates of correlation coefficients observed among fresh leaf stem percent cut 1, 2, 3 with LI%, SI and TI%. Total infection % (TI%) had positive and highly significant correlation with dry yield cut 1, 2, 3, total dry yield, plant height cut 1, 2, 3, stem diameter cut 1, 2, fresh leaf stem percent cut1, 2 and fresh leaf/stem percent cut 3. Meanwhile, relationship among total fresh forage yield with local infection % (LI %), systemic infection % (SI %) and total infection % (TI %) were insignificant and negative, meaning presence of non-influential losses in yield because most genotypes were resistant.

Keywords: Relationship; forage; silage; resistance; downy mildew; common smut; disease.

1. Introduction

The need to green food for livestock in summer season has been increased vigorously in Egypt. Therefore, great efforts have been directed towards to improve the productivity of summer fodder crops and study the differences among them. The differences in the fresh and dry forage yield potentialities were the highest in the first cut and declined in the second cut and were the lowest in the third cut and indicated that total fresh and dry forage in the two seasons ranked as follow was in a descending order Sorghum Sudan grass hybrid > Sudan grass > pearl millet > teosinte Ghasemi *et al*. (2021) and El-Shahawy and Tolba (1999).

Fodder crops in Egypt (Sorghum and pearl millet) are subject to attack of downy mildew disease which decreases yield and nutritive value (Allam *et al*. 2017; El-feky, *et al*., 2019;Elmahrouk, *et al*. 2021). Sorghum is counting as downy mildew host and the pathogen could be transferable to maize and causes great loses in seed production.

Carpici and Celik (2010) found positive and significant relationship between dry forage yield and each of the yield components, except for leaf/stem ratio. Moreover, Srivas and Singh (2004) stated that dry forage yield was significant and positive associated with fodder yield, plant height and stem diameter.

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Teosinte appears to have greater resistance against some pathogens and pests compared to their cultivated counterpart. Elivira *et al*. (2014) highlighted the need to study the teosinte in order to identify resistance traits that can be improved in maize. In addition, Wang *et al*. (2008) and Rich and Eteja (2008) found Mexican farmers occasionally use teosinte in maize crosses to improve their crop. Experimental crosses have been evaluated for pest resistance and indeed display increased resistance with respect to hybrid maize varieties to ear-infesting insects and various pathogens. Teosinte has also been evaluated for resistance in often aspects, such as the parasitic weed striges, for which no resistance in maize is known. In addition, Tolba (1996) tested number of maize genotypes against u-maydis. He classified them as resistant (infection mature 10%), moderately resistant (11-20%), susceptible (up to 50%) and highly susceptible (≥ 50%).

Maize (*Zea mays* L., ssp. mays) is one of the most important crops in the world cultivated for use in animal feed and biofuel. Teosinte (*Z. mays* ssp. Parviglumis Iltis x Doebley) and tripsacum are two crops wild relatives that have been extensively characterized as donors of economically important traits that could be used for improvement the maize. Hand crosses of greenhouse grown maize and teosinte were performed. Maize plants were detangled and newly shedding teosinte male inflorescence were shaken over respective maize silks. The resulting seeds were resistance to insects and germinated in pots and grown to maturity in the greenhouse (Ellstrand *et al*., 2007). Therefore, Durham (1998) found that crossing between teosinte or tripsa corn and maize is directed to the ability to confer resistance for root warms, insects and diseases in addition to drought tolerance and improved stand ability to maize via trips corn. The present study aimed to study the correlation, direct and indirect effects of yield components in some fodder crops as well as the importance of the resistance for downy mildew and common smut disease in forge improvement program.

2. Materials and methods

The present study was carried out in the field of diseases at Sakha Agric. Res. St. (Northern Delta) A.R.C., Egypt, during 2020 and 2021 summer seasons. Ten summer forage materials were used as fellow: A- Forage experiment (seven crops):

1. Saudia Arabia Millet (Imported pearl millet from Soudia),
2. Local pearl millet 1 (Local selected through breeding program, Forage Crops Res. Dept., ARC, Egypt),
3. Local pearl millet 2 (selected through breeding program, Forage Crops Res. Dept., ARC, Egypt),
4. Local pearl millet 3 (Local Shandawal 1, selected through breeding program, Forage Crops Res. Dept., ARC, Egypt),
5. Sorghum Giza 1 (Variety of Sorghum saccharatum),
6. Sorghum Piper Black (Selected through breeding program of Sudan grass, Forage Crops Res. Dept., ARC, Egypt) and
7. Sorghum SX-17 (Commercial hybrid sorghum imported) for forage and for silage are B- Silage experiment (three crops),
8. Teosinte (Sakha genotype, Forage Crops Res. Dept.),
9. Maize (SC168) and,
10. Maize * Teosinte (Maize SC168* Teosinte Sakha genotype).

The used forage crops were grown in a randomized complete blocks design (RCBD) with three replications. The plot size for each crop was 4.8 m2 (two ridges, 60 cm width, and four meter long) {1.2x4=4.8 m2}.

The seeding rates were 20 kg fed-1 for sorghum and millet, 30 kg fed^{-1} for teosinte, while 14 kg fed^{-1} for maize and, Maize x Teosinte hybrid and thinned to one plant in hill. Sowing date for first season was 15th Jun and fresh forage crops (7 genotypes) had cut after 50, 90 and 125 days from sowing date for first, second and third cut, respectively. While, silage forages had cut after 95 days from sowing for maize and 100 days for teosinte and their hybrid. Meanwhile, sowing date for second season was 17th Jun and fresh forage crops (7 genotypes) had cut after 49, 89 and 134 days from sowing date for first, second and third cut, respectively. While, Silage forages had cut after 96 for maize and 99 days for teosinte and their hybrid.

The seeds were planted in hills in the top ridges and were covered. The fertilizer rates were 200 Kg fed^{-1} super phosphate (15.5% P_2O_5) were added during land preparation. The nitrogen fertilizer was added at three equal doses (30 Kg fed^{-1}). The first dose was added after about 21 days from sowing, the second and the third doses were added after the first and the second cuts, respectively. While, for silage forages (3 genotypes) were 250 Kg nitrogen fed^{-1} were divided in to 125 Kg after about 21 days from sowing and 125 after 30-35 days from the first dose. Disease was assessed and expressed as infection percentage for downy mildew after 30 days from sowing and 30 days after cut in addition to common smut after 60 and 80 days from sowing. The infection percentage was expressed according to equation:

$$\text{Infection (\%)} = \frac{\text{No. of infected plants}}{\text{Total no. of plants (healthy + infected)}} \times 100$$

Common smut disease severity was classified into eight classes according to size of each gall and disease index (DI) adopted by Tolba (1996) as follows:

$$DI = \frac{\sum (NPC \times CR)}{NIP \times MSC} \times 100$$

Where: NPC = no. of plants in class rate, CR= Class rate, NIP = no. of inoculated plants and MSC= Maximum severity class rate.

The disease class rate was modified and suggested later as: 0 = no infection, 1 = galls was less than 1 cm in diameter, 2 = galls was 1 to less than 2 cm, 3 = galls was 2 to less than 3 cm, 4 = galls was 3 to less than 4 cm, 5 = galls was 4 to less than 5 cm, 6 = galls was 5 to less than 6 cm, 7 = galls was 6 to less than 7 cm, 8 = galls was 7 cm and more.

Appropriate agricultural practices were done during both growing seasons. Data recorded as:

1- Fresh forage yield per cut (kg plot^{-1}), 2- Dry forage yield per cut (kg plot^{-1}), 3-Plant height (cm), 4-Stem diameter (cm), 5- Fresh leaf/stem percent, 6-Total Fresh yield (kg plot^{-1}) and 7- Total dry yield (kg plot^{-1}).

Statistical analysis: Data were subjected to proper statistical analysis of RCBD design). As a necessary statistical step, Levene test (1960) was run prior to the combined analysis to confirm the homogeneity of individual error terms. Combined analysis of variance carried out according to Snedecore and Cochran (1986). Least significant of difference (LSD) test was used to detect the significant differences among the tested cultivars at 0.05 probability level. The statistical analyses were automated using Multiple range test was used to detect the significant differences among the tested materialsusing MSTAT-C (1986) computer program. Correlation was calculated as described by Wright (1921). A path coefficient analysis was performed according to Wright (1934).

3. Results and discussion

A- Forage experiment:

Analysis of variance

Data presented in Table (1) showed that there are significant differences at 0.05 probability levels among the seven genotypes over the two seasons and the three cuts for all studied traits i.e., plant height, stem diameter, fresh yield, dry yield and their total fresh and dry yields. These results were in line with those of Wright (1935), Radwan and Zayed (2021) and El-Gaafarey *et al*. (2023).

Mean performance

Data in Table (2) showed that piper black had the highest fresh (26.4, 22.3, 17.1 and 65.7 kg/plot) and dry forage yield (5.3, 2.8, 2.5 and 10.59 kg/plot) at first, second and third cut, respectively Ghasemi *et al*. (2021), Mekasha *et al*. (2022), Assaeed(1994) and Seadh *et al* (2022).

For millet, Shandawal 1 had 46.7 kg/plot and 7.8 kg/plot, while Saudia Arabia Millet gave 31.3 and 4.9 kg/plot, for total fresh and dry forage yields, meaning that Shandawal 1 surpass Saudia Arabia by 49.2 and 59.2 % for total fresh and dry forage yields, respectively. In addition, Saudia Arabia Millet had 12.8, 10.5, 80 and 31.3 kg/plot for fresh yield in first, second, third and total yield, respectively Dov Pasternak *et al* (2012).

For sorghum, piper black surpasses SX-17 by 19.2 and 26.5 % for total fresh and dry yield, respectively. Saudia Arabia Millet and hybrid SX-17 were susceptible to downy mildew disease, on the other hand pearl millet 2, 3, Giza 1 and piper black were resistance to downy mildew disease at the three cuts but Saudia Arabia Millet gave the lowest fresh and dry forage yields at the three cuts. Saudia Arabia Millet and hybrid SX-17 were susceptible to downy mildew disease on the other hand pearl millet 2,3,Giza 1 and piper black were resistance to downy mildew disease at the three cuts (El-shahawy 1991; El-Shahawy and Tolba 1999; Gheit and Tolba 2000; El-shahawy *et al* 2000).

Table 1. Analysis of variance over the two seasons for seven forage crops at the three cuts.

SOV	df	PHC1	PHC2	PHC3	SDC1	SDC2	SDC3	F/SPC1	F/SPC2	F/SPC3
Year (Y)	1	192.9*	94.5**	61.9*	0.1 *	0.03 *	0.02	21.4**	22.88**	13.7*
Reps/Y = Error (a)	4	13	1.1	3.5	0.008	0.004	0.01	0.5	0.88	1.57
Genotypes (G)	6	2240.4**	1596.9**	1411.7**	0.900**	0.67**	0.53**	221.7**	149.55**	186.85**
Y x G	6	2.4	1.5	1.4	0.007	0.004	0.01	0.42	1.54	0.71
Error (b)	24	30.8	33.6	27.6	0.03	0.02	0.02	5.3	6.13	8.65
Total	41									

Table 1. Cont.

SOV	df	FYC1	FYC2	FYC3	TFY	DYC1	DYC2	DYC3	TDY
Year (Y)	1	62.7**	23.6**	1.8**	199.8**	2.5**	0.30**	0.02**	5.4**
Reps/Y = Error (a)	4	0.5	0.1	0.2	0.3	0.1	0.001	0.001	0.01
Genotypes (G)	6	127.8**	94.9**	338.3**	815.3**	5.1**	1.5**	1.2 **	20.8**
Y x G	6	1.2	0.4	1.5	4.7*	0.1	0.006	0.005	0.1
Error (b)	24	3.1	2.0	28.5	1.5	0.1	0.04	0.03	0.07
Total	41								

Where: C = Cut, PH = Plant height, FY = Fresh yield, SD = Stem diameter, TFY = Total fresh yield, F.L/SP = Fresh leaf stem percent, DY = Dry yield, D.L/S.P = Dry leaf stem percent and TDY = Total dry yield.

Table 2. Fresh and dry forage yield (kg/plot)of studied seven forage crops to downy mildew disease under field disease nursly at three cuts and their total in both seasons ,combined analysis and Disease reaction.

Genotypes	Fresh forage yield (kg/plot)				Dry forage yield (kg/plot)				Disease reaction
	cut1	cut2	cut3	Total	cut1	cut2	cut3	Total	
Soudia Arabia Millet	12.8	10.5	8.0	31.3	2.60	1.20	1.10	4.90	Susceptible(S)
Local pearl millet 1 (Selection Millet 1)	17.3	14.5	11.0	42.8	3.50	1.90	1.70	7.04	Resistant(R}
Local pearl millet 2 (Selection Millet 2)	18.0	15.2	11.5	44.7	3.60	2.10	1.80	7.50	R
Local pearl millet 3 Millet Shandawal 1	18.8	15.8	12.2	46.7	3.80	2.10	1.90	7.80	R
S. Giza1	24.1	20.4	15.6	60.1	4.80	2.60	2.30	9.75	R
S. Piper B	26.4	22.3	17.1	65.7	5.30	2.80	2.50	10.59	R
S. SX-17	22.1	18.8	14.3	55.1	4.40	2.10	1.80	8.37	S
F test	**	**	**	**	**	**	**	**	-
L.S.D	2.1	1.7	1.3	1.5	0.40	0.30	0.20	0.32	-

Correlation coefficients

The efficiency of selection for yield mainly based on the direction and magnitude of association between yield and its components. The correlation among the traits in multi cut summer forage crops (seven crops) over the two years was discussed by correlation heat map analysis (Figure 1). Correlation coefficients were highly significant in positive direction among FYC1, FYC2, FYC3, TFY, FYC1, DYC1, DYC2, DYC3, TDY, PH1, PH2, PH3, SD1, SD2 and SD3, implying the effectiveness of these traits in selection for fresh forage yield. In addition, negative and insignificant correlation coefficients were observed between FYC1, FYC2, FYC3, TFY, FYC1, DYC1, DYC2, DYC3, TDY, PH1, PH2, PH3, SD1, SD2 and SD3, and each of FSpC1, FSRC2, FSRC3, LI%, SI and TI% traits, indicating that selection of low LI%, SI and TI% contribute to high estimates of these characters. In this respect, Gheit and Tolba (2000) and Bibi et al (2016) showed highly significant negative estimates of correlation coefficients were observed between FSRC1, FSRC2, FSRC3 with LI%, SI and TI%. Highly significant negative estimates of correlation coefficients were observed between FSRC1, FSRC2, FSRC3 with LI%, SI and TI% Gheit and Tolba (2000) and Bibi *et al* (2016). Also, total infection % (TI%) had positive and significant correlation coefficients between DYC1, 2, 3, total dry yield, PH1, 2, 3, SD1, 2, 3 F/SP C1, 2 and F.SRC3. Meanwhile, relationship between total fresh forage yield with local infection % (LI%), systemic infection% (SI%) and total infection % (TI%) were negative and insignificant. These results indicate that there were non-influential losses in yield because most genotypes were resistant (Robbinson *et al*., 1951; Bakheit, 1986; Iyanar *et al*., 2010; Sharma *et al*., 2018).

Path coefficient analysis:

Path coefficient analysis was used to determine the direct and indirect effects and measures the relative importance of the causal factor individually (Dewey and Lue, 1959 and El-Shahawy and Tolba, 1999). Path coefficient analysis (direct) and indirect effects of the studied traits on the total fresh forage yield for the summer forage crops (seven crops) over the two years are presented in Table (3). Total fresh forage yield as independent trait has been affected with other traits like plant height. The highest positive direct effect on total fresh forage yield were obtained by FYC2, DYC2, DYC3, PH1 and SD2 which had (0.141), (0.149), (0.108), (0.107) and (0.113), respectively. These results are in harmony with those of Bakheit (1986), Nakawuka and Adipala (1999) and Iyanar *et al* (2010).

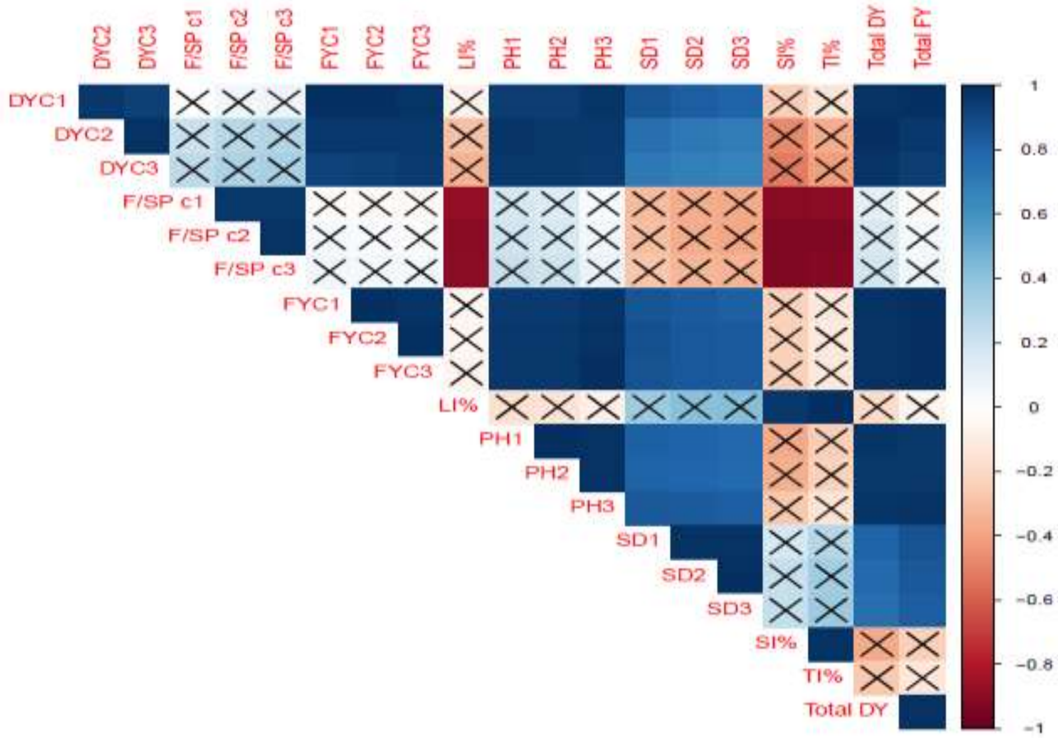

Fig. 1. Pearson correlation heat map among the traits in multi cut summer forage crops (seven crops) over the two years. The values are shown in different colours in the figure. The right legend is the colour range of different values. insignificant values are shown with X symbols. FYC1: fresh forage yield cut 1; FYC2: fresh forage yield cut 2; FYC3; fresh forage yield cut 3; DYC1; Dry forage yield cut 1; DYC2: Dry forage yield cut 2; DYC3: Dry forage yield cut 3; PH1: plant height cut1; PH2: plant height cut2; PH3: plant height cut3; SD1: stem diameter cut1; SD2: stem diameter cut2; SD3: stem diameter cut3 ; F/SP c1: fresh leaf/ stem percent cut1; F/SP c2: fresh leaf /stem percent cut2; F/SP c3: fresh leaf /stem percent cut3; LI%: Local infection %; SI%: Systemic infection%; TI%: Total infection %.

Table 3. Direct (in diagonal within bracts), indirect effects and total indirect effects (T) for the estimated nineteen characters on total fresh forage yield for multi cuts in seven summer crops over the two years.

Trait	FYC1	FYC2	FYC3	DYC1	DYC2	DYC3	Total DY	PH1	PH2	PH3	SD1	SD2	SD3	F/SP c1	F/SP c2	F/SP c3	LI%	SI%	TI%	Total correlation
FYC1	(0.64)	0.14	0.06	-0.181	0.14	0.09	0.06	0.100	-0.06	-0.04	0.03	0.09	-0.09	0.01	0.01	-0.01	0.01	0.01	-0.01	0.99
FYC2	0.64	(0.14)	0.06	-0.181	0.14	0.09	0.06	0.100	-0.06	-0.04	0.03	0.09	-0.09	-0.01	0.01	-0.01	0.01	0.01	-0.01	1.00
FYC3	0.63	0.14	(0.06)	-0.181	0.14	0.10	0.06	0.100	-0.06	-0.04	0.03	0.09	-0.09	-0.01	0.01	-0.01	0.01	0.01	-0.01	0.99
DYC1	0.64	0.14	0.06	(-0.18)	0.14	0.09	0.06	0.100	-0.06	-0.04	0.03	0.09	-0.08	0.01	0.01	-0.01	0.01	-0.01	-0.01	0.99
DYC2	0.61	0.13	0.06	-0.18	(0.14)	0.10	0.06	0.100	-0.06	-0.04	0.03	0.08	-0.07	-0.01	0.01	-0.02	0.01	-0.01	-0.01	0.97
DYC3	0.59	0.13	0.06	-0.17	0.14	(0.10)	0.06	0.100	-0.06	-0.04	0.02	0.08	-0.07	-0.01	0.01	-0.01	0.01	-0.01	-0.01	0.94
Total DY	0.63	0.14	0.06	-0.18	0.14	0.10	(0.06)	0.100	-0.06	-0.04	0.03	0.08	-0.08	-0.01	0.01	-0.01	0.01	0.01	-0.01	0.99
PH1	0.61	0.13	0.06	-0.17	0.14	0.10	0.06	(0.107)	-0.06	-0.04	0.03	0.09	-0.08	-0.01	0.01	-0.01	0.01	0.01	-0.01	0.96
PH2	0.61	0.13	0.06	-0.17	0.14	0.10	0.06	0.100	(-0.06)	-0.04	0.03	0.09	-0.08	-0.01	0.01	-0.01	0.01	0.01	-0.01	0.96
PH3	0.62	0.13	0.06	-0.18	0.14	0.10	0.06	0.100	-0.06	(-0.04)	0.03	0.09	-0.09	-0.01	0.01	-0.01	0.01	-0.01	-0.01	0.98
SD1	0.55	0.12	0.06	-0.15	0.11	0.70	0.05	0.080	-0.05	0.01	(0.04)	0.11	-0.11	-0.01	0.01	-0.02	0.01	-0.01	-0.01	0.87
SD2	0.52	0.12	0.06	-0.15	0.11	0.07	0.05	0.085	-0.05	0.01	0.04	(0.11)	-0.11	-0.01	0.01	-0.01	0.01	0.01	-0.01	0.84
SD3	0.52	0.17	0.05	-0.15	0.10	0.07	0.05	0.083	-0.05	0.01	0.04	0.11	(-0.11)	-0.01	0.01	-0.01	0.01	0.01	-0.01	0.83
F/SP c1	0.01	0.01	0.01	0.01	0.03	0.03	0.01	0.018	0.01	0.01	0.01	0.02	-0.02	(-0.031)	0.02	-0.06	0.01	-0.01	-0.02	0.02
F/SP c2	0.01	0.01	0.01	-0.01	0.04	0.02	0.01	0.020	-0.01	0.01	0.01	0.02	-0.02	-0.031	(0.02)	-0.06	0.01	-0.02	-0.02	0.02
F/SP c3	0.03	0.01	0.01	-0.01	0.04	0.02	0.01	0.020	-0.01	0.01	0.01	0.02	-0.02	-0.031	0.02	(-0.06)	0.01	-0.02	-0.02	0.05
LI%	0.03	0.01	0.01	-0.01	0.04	0.02	0.01	0.017	-0.01	0.01	0.01	0.04	-0.05	-0.03	0.02	-0.06	(0.02)	-0.02	-0.02	0.05
SI%	0.14	0.03	0.01	-0.05	0.07	0.06	0.01	0.023	-0.01	0.01	0.01	0.03	-0.02	-0.03	0.02	-0.06	0.02	(-0.01)	-0.02	0.22
TI%	0.08	0.02	0.01	-0.02	0.03	0.04	0.02	0.026	-0.02	0.01	0.01	0.02	-0.02	-0.03	0.02	-0.06	0.02	-0.01	(-0.02)	0.12

FYC1 = fresh forage yield cut 1, FYC2 = fresh forage yield cut 2, FYC3 = fresh forage yield cut 3, DYC1 = Dry forage yield cut 1, DYC2 = Dry forage yield cut 2, DYC3 = Dry forage yield cut 3, Total DY = Total Dry yield, PH1 = plant height cut1, PH2 = plant height cut2, PH3 = plant height cut3, SD1 = stem diameter cut1, SD2 = stem diameter cut2 , SD3 = stem diameter cut3 , F/SP c1 = fresh leaf/ stem percent cut1, F/SP c2 = fresh leaf /stem percent cut2, F/SP c3 = fresh leaf /stem percent cut3, LI% = Local infection %, SI% = Systemic infection% and TI% = Total infection %.

B- Silage experiment

Analysis of variance

Data in Table (4) mentioned that these are significant differences among the three crops for silage fresh, dry yield and its components.

Mean performance

Mean performance of the studied characters of three studied forage crops for silage for combined data are presented in Table (5). Hybrid maize x teosinte had the highest values of plant height, stem diameter fresh leaf/stem percent, fresh and dry forage yields, while maize gave the lowest values (Elvira *et al* 2014; Wang, *et al* 2008; Rich and Eteja 2008). Teosinte is susceptible while maize and hybrid maize x teosinte were moderate susceptible to common smut disease infection Tolba (1996). Maize SC168 x Teosinte Sakha showed the highest values of plant height (298 cm), stem diameter (2.9 cm), fresh/leaf stem percent (81%) and fresh forage yield (69 kg/plot). Maize SC168 x Teosinte Sakha exceed teosinte by 5.7, 93.3, 24.6 and 8.7% and maize SC168 by 11.2,16.0,72.3 and 122.6% for plant height, stem diameter, fresh/leaf stem percent and fresh forage yield, respectively (Abdlaty *et al.* 2013). It can be concluded that hybrid maize x teosinte was the best silage fresh yield, where it had more than twice maize silage (122.6%),while maize can be used in breeding program to transfer common smut disease to teosinte and hybrids (Aulicino 1991; Chaudhuri and Prasad 1969).

Correlation coefficients

The correlation among the traits for silage fresh, dry yield and its components in over the two years (three crops) was discussed by correlation heat map analysis (Figure 2). Significant and positive correlations were found between fresh forage yield (FY) and Dry forage yield (DY), plant height (PH) and fresh leaf/ stem percent (F/SP), indicating that increased these traits lead to increased fresh forage yield. On the other hand, there were negative and significant correlations among reading 1 of downy mildew local infection % (R1DMLI), reading 1 of downy mildew total infection % (R1DMTI) and reading 2 of downy mildew total infection % (R2DMTI). These results are in accordance of Robbinson *et al* (1951), Iyanar *et al* (2010), Ghanbarian and Hurst (2015) and Sharma *et al* (2018). Meanwhile, reading 1 of common smut disease index (R1DICS) had insignificant and negative correlation with plant height, highly significant and negative correlation with stem diameter. In addition, there were negative and significant correlations between stem diameter and each of reading 1 of common smut infection % (R1ICS), reading 2 of common smut disease index (R2DICS) and reading 2 of common smut infection % (R2ICS).

Path coefficient analysis

Data in Table (6) showed that Reading 1 Local infection % (downy mildew (R1 DM) (LI), Reading 1 Systemic infection% downy mildew (R1 DM) (SI)and Reading 1 Disease index common smut (R1 DICS) had negative direct effect on fresh forage yield which had (-4.306), (-1.639) and (-0.848) which mean decreased fresh forage yield but these crops were resistant (R) and moderated resistant (MR) (Iyanar *et al* 2010 and De Lange *et al* 2014).

Data presented in Table 7 found that, the oospores of prenosclerospora sorghi were highly significantly (+++) founded in the soil around all tested genotypes, during the two tested seasons. While, it was not found in plant tissues of pearl millet 1 (Saudia Arabia) and pearl millet 3 (-) during two tested seasons (Chavan and Smith2014). Moreover, it was low found in plant tissues (+) in pearl millets 1,3 and piper black during two tested seasons, while in case of Giza 1 the oospores of the tested pathogen found in low during the first season only (season 2020). On the other hand, the oospores of tested pathogen were highly significantly founded (+++) in soil of imported pearl millet (Suodia pearl millet) and SX-17 genotypes during two tested season These results were in the same line with founded by Elvira *et al* (2014) and Wang *et al* (2008).

Table 4. Analysis of variance of two seasons and combined data for three forage crops for silage.

SOV	df	PH	SD	F/SP	FY
Year (Y)	1	72	0.08	45.5	0.5
Reps/Y = Error (a)	4	17.3	0.003	1.833	2.7
Genotypes (G)	2	1352**	3.185**	1684.5**	2530.5**
Y x G	2	96 Ns	0.005 Ns	9.5 Ns	12.5 Ns
Error (b)	8	38.58	0.068	12.833	20.38
Total	17				

* and ** = significant at 0.05 and 0.01 levels probability, respectively. PH = plant height, SD = stem diameter, F/SP = fresh leaf/stem percent cut1 and FY = fresh yield.

Table 5. Mean performance of fresh and dry forage yields (kg/plot) of three forage crops for silage for combined of the two seasons and reaction to common smut disease under natural infection.

Genotypes	Plant height cm	Stem diameter	Fresh leaf stem%	Fresh forage yield (kg/plot)	Dry forage yield (kg/plot)	Disease reaction
Teosinte	282	1.5	65	63.5	18.1	S
Maize	268	2.5	47	31	7.3	MR
Maize × Teosinte (H.)	298	2.9	81	69	17.6	MR
F test	**	**	**	**	**	-
LSD	8.27	0.347	4.769	6.01	1.88	-
percent of increase % from teosinte	5.7	93.3	24.6	8.7	-	-
percent of increase % from maize	11.2	16.0	72.3	122.6	-	-

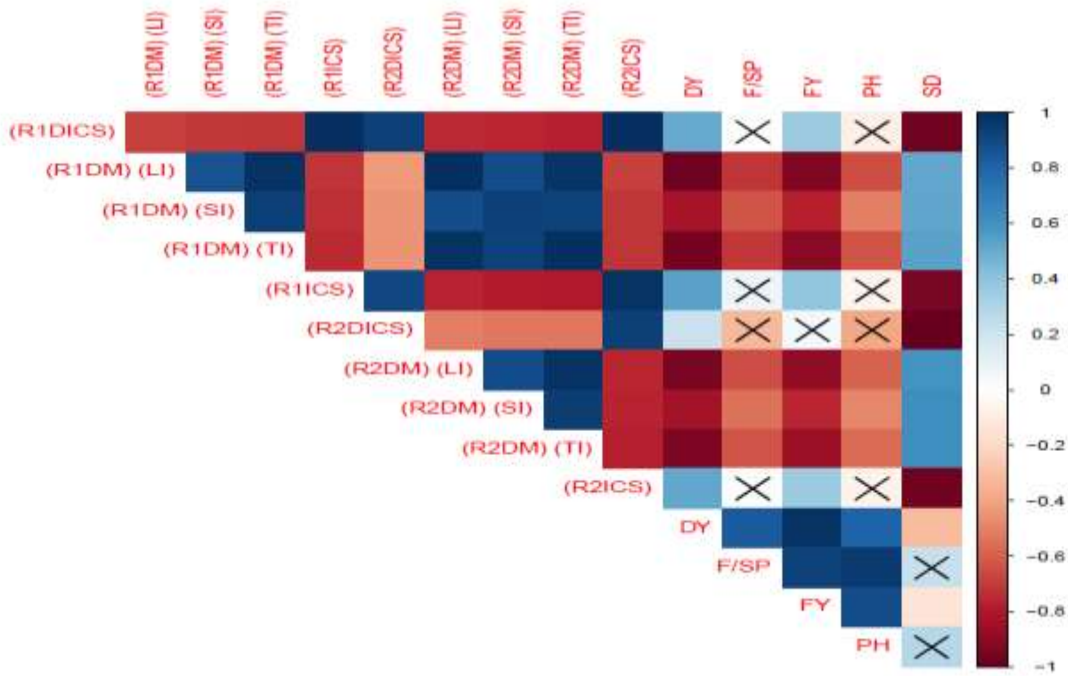

Fig. 2. Pearson correlation heat map among the traits in summer forage crops (three crops) for silage over the two years. The values are shown in different colours in the figure. The right legend is the colour range of different values. insignificant values are shown with X symbols. FY: fresh forage yield; DY: Dry forage yield; PH: plant height; SD: stem diameter; F/SP: fresh leaf/ stem percent; (R1 DM) (LI); Reading 1 Local infection % (downy mildew) ; (R1 DM) (SI): Reading 1 Systemic infection% (downy mildew); (R2DM) (LI): Reading 2 Local infection % (downy mildew); (R2DM) (SI): Reading 2 Systemic infection% (downy mildew); (R2DM) (TI): Reading 2 Total infection % (downy mildew); (R1 DICS): Reading 1 Disease index common smut; (R1 ICS) : Reading 1 Infection % common smut; (R1 ICS): Reading 1 Infection % common smut; (R2DICS): Reading 2 Disease index common smut; (R2ICS): Reading 2 Infection % common smut.

Table 6. Path coefficient analysis (direct) and indirect effects of the studied traits on fresh forage yield for summer forage crops (three crops) for silage over two years.

combined	DY	PH	SD	F/SP	(R1 DM) (LI)	(R1 DM) (SI)	(R1 DM) (TI))	(R2DM) (LI))	(R2DM) (SI)	(R2DM) (TI))	(R1 DICS)	(R1 ICS)	(R2 DICS)	(R2 ICS)	Total correlation
DY	(2.573)	-0.006	-0.815	0.007	-4.195	-1.354	3.515	0.064	0.185	-0.002	-0.431	0.735	0.378	0.329	0.984
PH	2.071	(-0.008)	-0.722	0.008	-2.795	-0.836	2.293	0.039	0.108	-0.001	-0.073	0.076	0.678	0.040	0.88
SD	0.813	-0.002	(-2.581)	0.002	-2.213	-0.865	1.965	0.04	0.137	-0.001	-0.82	1.291	1.764	0.617	0.147
(R1DM) (LI)	2.159	-0.008	-0.578	(0.009)	-3.006	-1.017	2.588	0.440	0.121	-0.002	-0.008	0.089	0.579	0.006	0.921
(R1DM) (SI)	2.500	-0.005	-1.327	0.006	(-4.306)	-1.420	3.629	0.067	0.197	-0.003	-0.582	0.974	0.748	0.438	0.924
(R1DM) (TI)	2.126	-0.004	-1.363	0.005	-3.729	(-1.639)	3.449	0.060	0.208	-0.002	-0.595	1.013	0.789	0.457	0.774
(R2DM) (LI)	2.458	-0.005	-1.378	0.006	-4.246	-1.536	(3.681)	0.067	0.206	-0.003	-0.604	1.016	0.783	0.457	0.902
(R2DM) (SI)	2.437	-0.004	-1.528	0.005	-4.268	-1.454	3.633	(0.068)	0.198	-0.003	-0.635	1.050	0.899	0.482	0.882
(R2DM) (TI)	2.138	-0.004	-1.592	0.005	-3.807	-1.531	3.415	0.060	(0.222)	-0.002	-0.642	1.071	0.929	0.488	0.751
(R1DICS)	2.398	-0.004	-1.587	0.005	-4.220	-1.518	3.651	0.067	0.211	(-0.003)	-0.653	1.083	0.932	0.497	0.860
(R1ICS)	1.310	-0.001	-2.490	0.001	-2.958	-1.151	2.624	0.051	0.168	0.000	(-0.848)	1.363	1.666	0.633	0.360
(R2DICS)	1.382	-0.004	-2.434	0.001	-3.062	-1.213	2.731	0.052	0.174	0.000	-0.843	(1.369)	1.615	0.625	0.398
(R2ICS)	0.548	-0.003	-2.563	0.003	-1.813	-0.728	1.623	0.035	0.117	0.000	-0.795	1.245	(1.777)	0.599	0.043

DY = Dry forage yield, PH = plant height, SD = stem diameter, F/SP = fresh leaf/ stem percent, (R1 DM) (LI), Reading 1 Local infection % (downy mildew) , (R1 DM) (SI) = Reading 1 Systemic infection% (downy mildew), (R2DM) (LI) = Reading 2 Local infection % (downy mildew), (R2DM) (SI) = Reading 2 Systemic infection% (downy mildew), (R2DM) (TI) = Reading 2 Total infection % (downymildew), (R1 DICS) = Reading 1 Disease index common smut, (R1 ICS) = Reading 1 Infection % common smut, (R1 ICS) = Reading 1 Infection % common smut, (R2DICS) = Reading 2Disease index common smut, (R2 ICS) = Reading 2 Infection % commonsmut

Table 7. Residual oospores of Prenosclerospora sorghi after harvest in soil and plant tissues over two seasons.

Genotypes	In plant tissues	In the soil
Soudia Arabia Millet	-	+++
Local pearl millet 1 (Selection Millet 1)	+	+++
Local pearl millet 2 (Selection Millet 2)	-	+++
Local pearl millet 3 (Millet Shandawal 1)	+++	+++
S. Giza1	-	+++
S. Piper B	+	+++
S. SX-17	+++	+++

4. CONCLUSION

The efficiency of selection for yield mainly based on the direction and magnitude of association between yield and its components as well as among yield component traits. However, the correlation analysis provides useful information on the nature and magnitude of association of different component traits with yield in addition to the nature of interrelation ships among the component traits themselves. Also, total infection % (TI%) had positive and highly significant correlation with DYC1, 2, 3, total dry yield, PH1, 2 ,3, SD1, 2, 3 F/SP C1, 2 and F.SRC3. Meanwhile, relationship between total fresh forage yield with local infection % (LI%), systemic infection% (SI%) and Total infection % (TI%) was negative and insignificant, meaning presence of non-influential losses in yield because most genotypes were resistant.

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