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REGULAR PAPER

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Evaluation of morphological and production characteristics and nutritive value of 47 lucerne cultivars/lines in temperate Australia

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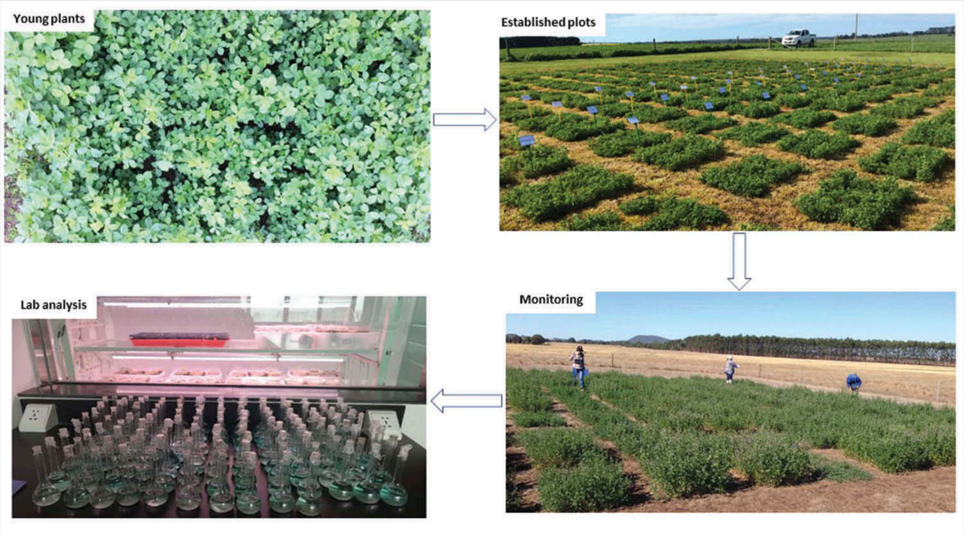
ABSTRACT

Forty-seven lucerne varieties/lines were examined to quantify their morphological, production characteristics, and nutritive values in southeastern Australia. The experiment was established in 2015 with a randomized complete block design and four replications. The morphological and production characteristics were measured from January to October 2017, and nutritive values were measured in February 2017. The results showed that the cultivars differed significantly ($P < 0.01$) in morphological, production characteristics, and nutritive values. Total herbage yield was highest for Haymaster 7 (14,186 kg/ha) and lowest for Qingshui (5927 kg/ha). Plant height was highest for Cropper 9.5 (31.4 cm) and lowest for Qingshui (14.5 cm). SF 714QL had the greatest branch number (44.7 branches/15 cm row segment). AV1001 had longest leaf (2.3 cm) and greatest leaf area (16.68 cm^2/10 leaves) whereas Force 10 and SARDI 10 SERIES 2 had widest leaves (1.3 cm). AV1005 had the highest leaf-to-stem ratio (5.64). Crude protein (CP) content was highest for SARDI 10 SERIES 2 (15.1%) and lowest for SF 714QL (8.0%). AV12 was highest in crude fat (4.5%). Neutral detergent fiber (NDF) content was lowest in Stamina 5 (33.5%). Acid detergent fiber (ADF) content was lowest in Gannong 4 (29.3%). Relative feed value (RFV) was highest in Force 11 (193.0%). Calcium (Ca) content was highest for Titan 5 (1.8%). Phosphorous content was highest for AV1 and Gannong 6 (0.1%). Overall, Cropper 9.5, SARDI 10 SERIES 2, Haymaster 9, Titan 9, SF 714QL, Kaituna, Haymaster 7, AV1001, AV1002, and WL925HQ performed well based on their comprehensive scores.



Evaluation of 47 lucerne varieties/lines in southern Australia

Abbreviations: CP - crude protein; CF - crude fat; NDF - neutral detergent fiber; ADF - acid detergent fiber; Ca - calcium; P - phosphorus; RFV - relative feed value.

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1. Introduction

Lucerne (or alfalfa, *Medicago sativa* L.) is a perennial pasture legume sown over an area of around 3.2 M ha in southern and subtropical areas of Australia (Robertson, 2006) and is used directly for grazing, for the production of high-quality fodder (mainly hay) (Irwin, Lloyd & Lowe, 2001; Lodge, 1991), for augmenting soil nitrogen and carbon stocks (Angus and Peoples, 2012), and for improving soil structure (Hanley, Ridgman & Jarvis, 1964) and water infiltration (McCallum et al., 2004). Numerous cultivars have been developed worldwide using highly divergent genetic materials and different breeding methods. Cultivars and their genetic characteristics crucially determine the volume and stability of yield, as well as the quality of feed. Lucerne breeding requires that varieties have certain overlapping traits such as adaptation, proper winter dormancy, targeted pest resistances, and tolerance to grazing, acid and aluminum-toxic soils, and drought (Bouton, 2012).

Selecting the most suitable varieties of lucerne is a challenge for farmers. Many lucerne germplasm options from different genotypes are available to match different combinations of farming systems, climate and soil type. Lucerne's role as the best performing forage legume in Australian pastoral agriculture has been, and continues to be, high, which increases the need for breeding new cultivars for the diverse and challenging Australian environments (Venkatanagappa, 2008). Thus the effective screening and comprehensive evaluation of lucerne varieties are critical to identify traits that can be used in practice or for new cultivar development. Lucerne cultivars with excellent comprehensive traits are desirable for popularization and utilization.

The objectives of this study were to examine the morphological and production characteristics, and nutritive values of 47 lucerne varieties, compare their suitability for high rainfall conditions, and identify desirable traits for practical implementation and further cultivar development.

2. Materials and methods

2.1. Study site

A field experiment was carried out at the research farm of Department of Jobs, Precincts and Regions near Hamilton (S37.834, E142.086), Victoria, Australia. The soil of the site was a ferric-sodic eutrophic brown Chromosol (Isbell, 2002). The long-term (1965–2015) average maximum and minimum monthly temperature were 18.4°C (12.0°C in July–25.9°C in February) and 7.1°C (4.2°C in July–10.9°C in February). The long-term average annual rainfall was 684 mm. The average maximum and minimum monthly temperature over the experimental phase (2015–2017) were 19.5°C and 8.1°C, slightly higher than the long-term averages. The average annual rainfall was 680.2 mm over this phase, similar to the long-term average.

2.2. Crop establishment and experimental design

Forty-one varieties/lines from Australian gene banks/companies and six varieties from China (*M. sativa* cvv Gannong No. 3, 4, 5, 6, and 9, and *M. sativa* cv Qingshui) were evaluated (Table 1). The experiment was sown on

Table 1. Forty-one lucerne varieties/lines from Australian gene banks/companies and 6 varieties from China (*Medicago. sativa* cvv Gannong No. 3, 4, 5, 6, and 9, and *M. sativa* cvv Qingshui) used for the experiment.

Variety	Source	Variety	Source
54Q53	Pioneer Narromine NSW	L34HQ	Stephen Pasture Seeds
57Q75	Pioneer Narromine NSW	L55	Pioneer Narromine NSW
Cropper 9.5	PGG Wrightson Seeds	L90	Stephen Pasture Seeds
AV1	PIRSA SARDI	AV1001	PGG Wrightson Seeds
AV2	PIRSA SARDI	AV1002	PGG Wrightson Seeds
AV3	PIRSA SARDI	Titan 5	PGG Wrightson Seeds
Force 10	Seed Force	Haymaster 9	PGG Wrightson Seeds
Force 11	Seed Force	AV1003	PGG Wrightson Seeds
Force 5	Seed Force	AV1004	PGG Wrightson Seeds
Force 7	Seed Force	AV1005	PGG Wrightson Seeds
Gannong 3	Gansu Agricultural University, Lanzhou, China	Qingshui	Gansu Agricultural University, Lanzhou, China
Gannong 4	Gansu Agricultural University, Lanzhou, China	SARDI 10 SERIES 2	Heritage Seeds
Gannong 5	Gansu Agricultural University, Lanzhou, China	SARDI 5	Heritage Seeds
Gannong 6	Gansu Agricultural University, Lanzhou, China	SARDI 7	Australian Pastures Genebank
Gannong 9	Gansu Agricultural University, Lanzhou, China	SARDI 7 SERIES 2	PIRSA SARDI
Haymaster 7	PGG Wrightson Seeds	SARDI AT7	Heritage Seeds
AV09	PIRSA SARDI	SARDI GRAZER	PIRSA SARDI
AV10	PIRSA SARDI	SF 714QL	Seed Force
AV11	PIRSA SARDI	Stamina 5	PGG Wrightson Seeds
AV12	PIRSA SARDI	Stamina GT6	PGG Wrightson Seeds
AV13	PIRSA SARDI	Titan 7	PGG Wrightson Seeds
AV14	PIRSA SARDI	Titan 9	PGG Wrightson Seeds
Kaituna	Wrightson Seeds	WL925HQ	PGG Wrightson Seeds
KI Creeper	TasGlobal Seeds		

8 October 2015 using a randomized complete block (RCB) design with four replications. Plots were 1 m × 0.6 m and consisted of 5 × 1 m drill rows 15 cm apart. The sowing rate was 12 kg/ha for SARDI SEVEN, which was used as the base for adjusting all other lines according to their seed size and germination percentage. Assessments were conducted when obvious differences occurred or at 6-week intervals maximum. Weeds, pests and diseases were controlled using recommended herbicides/pesticides when necessary.

2.3. Herbage yield

On each harvest occasion the plot that had the highest herbage mass was identified and given a score of 9. All plots were then scored 0, 1, 3, 5, 7 or 9 relative to the best plot. These scores were calibrated by cutting and weighing 15–20 plots to cover the range of herbage mass present on the day following the assessment of all parameters. Subsamples were taken, weighed fresh, dried (24 h at 100°C) and weighed dry to determine DM%.

2.4. Lucerne morphological characteristics

Absolute plant height (cm) was measured from the ground to the highest part of each of four plants per plot. The number of branches was measured in two 15-cm row segments per plot. Fresh herbage samples (one per plot) were then collected by taking 5 cuts per plot (4 about 10–20 cm from each corner and one in the centre). Leaf-to-stem ratio (%) was measured by taking 500 g subsamples, which were separated into stems and leaves, oven dried at 60°C for 48 h and weighed. The leaf length (cm) and width (cm) were measured by randomly selecting three leaflets at the upper part of the branches from each sample. Leaf area (cm^2) was measured by taking 10 upper, middle, and lower leaves from branches of each sample.

2.5. Nutrient analysis

The concentration (%) of crude protein (CP), crude fat (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), calcium (Ca), and phosphorous (P) was measured by collecting lucerne herbage samples on 17 February 2017. The samples were oven dried at 60° C for 48 h. CP content was determined by Kjeldahl method (GB/6432-94 standard, 1994). CF content was measured by Soxhlet extraction method (GB/T 6433-2006 standard, 2006). NDF and ADF contents were determined by gravimetric method (GB/T 2080–2006 standard, 2006; NY/T 1459-2007, 2007). Ca content was analyzed by EDTA titration (GB/T 6436, 2002). P content was determined by spectrophotometric method (GB/T 6437, 2002). Relative feed value (RFV) is a widely accepted forage quality index, and forages with RFV greater than 100 are considered to have better quality than full bloom lucerne herbage and those with RFV lower than 100 are regarded as of lower quality than the lucerne herbage quality in full bloom. The parameter is considered to be of useful practical significance in forage pricing and marketing (Schroeder, 2013), and was calculated as:

$$\mathrm{RFV}(\%) = (88.9 - 0.779 \times \mathrm{ADF}) \times (120/\mathrm{NDF})/1.29$$

2.6. Statistical analysis

Analysis of variance (RCB design) and correlation analysis were performed using SPSS 16.0 (SPSS Inc., Chicago, IL, USA). Significant difference was denoted as $P < 0.05$ or $P < 0.01$ when the probability was less than 5 or 1%, respectively. The integrated evaluation of herbage yield and quality was performed by grey relational analysis, an analytical method used to identify correlations between characteristic data sequences and their related factor sequences affecting the system behaviors, with an ultimate goal of understanding broad system behaviors. After calculating the correlation between the major system behaviors and the influencing factors, certain data are processed to form a quantitative description of the influence of the factors on the whole system (Deng, 2010; Liu, Dang & Fang, 2004). The procedure of grey relational analysis consists of the following steps (Jin et al., 2013):

1. Generation of reference data series X_0:

$$X_0 = [d_{01}, d_{02}, \ldots, d_{0m}], \tag{1}$$

where m is the number of respondents. In general, the X_0 reference data series consists of m values representing the optimal value.

2. Generation of comparison data series X_i:

$$X_i = [d_{i1}, d_{i2}, \ldots, d_{imk}], \tag{2}$$

where i = 1, .., k, and k is the number of scale items. There will be k comparison data series and each comparison data series will contain m values.

3. The difference data series (i.e. absolute deviation) Δ_i is computed:

$$\Delta_i = [|d_{01} - d_{i1}|, |d_{02} - d_{i2}|, \ldots |d_{0m} - d_{im}|] \tag{3}$$

4. The global maximum value Δ_{max} and minimum value Δ_{min} in the difference data series are determined:

$$A_{\max} = \overset{\max}{U_i}(\max \Delta_i), \quad (4)$$

$$A_{\min} = \overset{\min}{U_i}(\min \Delta_i). \quad (5)$$

5. Each data point in each difference data series is transformed to generate a grey relational coefficient ζ. Let $r_i(j)$ represent the grey relational coefficient of the jth data point in the ith difference data series, then

$$r_i(j) = \frac{\Delta_{\min} - \xi\Delta_{\max}}{\Delta_i(j) + \xi\Delta_{\max}}, \quad (6)$$

where Δ_i (j) is the jth value in Δ_i difference data series, and ζ is a coefficient that takes a value between 0 and 1. In general, the value of ζ can be set to 0.5.

6. A grey relational grade is computed for each difference data series. Let Γ_i represent the grey relational grade for the ith scale item and assume that data points in the series are of the same weights, then

$$\Gamma_i = \frac{1}{m}\sum_{m}^{n=1} r_i(n). \quad (7)$$

The magnitude of Γ_i reflects the overall degree of standardized deviance of the ith original data series from the reference data series.

7. Weight coefficient (W_i) is calculated as:

$$W_i = \frac{\Gamma_i}{\Sigma\Gamma_i}. \quad (8)$$

8. Weighted relation coefficient ($r_{\prime}$) is calculated as:

$$\Gamma_i' = \sum_{k=1}^{m} w_i(k) r_i(n). \quad (9)$$

In this study, 10 indicators of plant height, leaf-to-stem ratio, yield, CP, CF, ADF, NDF, Ca, P, and RFV were selected and the average values of several indicators in the different seasons are calculated respectively. With the calculated averages of the 10 indicators, absolute deviation, correlation coefficient, equal correlation degree, weight coefficient, and weighted relation coefficient are calculated according to Equations (3), (6), (7), (8), and (9).

3. Results

3.1. Leaf length, width and area

There were significant differences ($P < 0.01$) in leaf length, leaf width, and leaf areas among cultivars except for leaf width in autumn (Table 2). The leaf length ranged from 1.3 to 2.4 cm, 1.4 to 2.2 cm, 0.6 to 2.5 cm, 1.3 to 2.2 cm in summer, autumn, early winter, and late winter, respectively. The average leaf length was considerably higher for AV1001, Cropper 9.5, and Titan 9 than the rest of lucerne cultivars, whereas AV2 and Qingshui had shorter leaves than other lucerne cultivars from summer to late winter.

Leaf width ranged from 0.6 to 1.1 cm, 0.7 to 1.1 cm, 0.6 to 1.8 cm, and 1.0 to 1.6 cm in summer, autumn, early winter, and late winter respectively. The average leaf width was considerably higher for Force 10 and SARDI 10 SERIES 2 than other lucerne cultivars, whereas AV2, AV3, Gannong 4, KI Creeper, and Qingshui had significantly narrower leaves than other lucerne cultivars from summer to late winter.

The leaf area ranged from 9.09 to 15.11 cm^2, 5.77 to 13.45 cm^2, 3.98 to 23.48 cm^2, 11.62 to 21.68 cm^2 per 10 leaves in summer, autumn, in early winter, and late winter respectively. The average leaf area was highest for Cropper 9.5, AV1001, and Titan 9, but lowest for AV2, AV3, and Qingshui from summer to late winter.

3.2. Herbage yield attributes

The cultivars differed significantly ($P < 0.01$) in plant height, leaf-to-stem ratio, number of branches, and herbage yield (Tables 3 and 4). The plant height ranged from 23.6 to 47.0 cm, 12.0 to 34.0 cm, 3.7 to 22.3 cm, and 12.1 to 28.6 cm in summer, autumn, early winter, and late winter, respectively. The average plant height was highest for Cropper 9.5 and Titan 9, high for Force 10, AV1001, Haymaster 9, and SARDI 10 SERIES 2, and lowest for Qingshui and Gannong 3 from summer to late winter.

Leaf-to-stem ratio ranged from 0.91 to 3.00, 1.99 to 7.79, 2.52 to 3.43 in summer, autumn, and late winter respectively. In early winter, 54Q53, AV1, AV2, AV3, Gannong 3, Gannong 4, Gannong 6, Gannong 9, AV09, AV12, AV13, KI Creeper, L34HQ, Qingshui, and SARDI 5 did not have the stem component. Gannong 4 and Qingshui had the highest and AV1001, AV14, and Haymaster 9 the lowest leaf-to-stem ratio. The average leaf-to-stem ratio of the four harvests was the highest for AV11 (5.22) and AV1005 (5.64) and the lowest for AV1 (2.14) and SARDI 5 (2.11).

The number of branches ranged from 19.5 to 45.3, 18.0 to 49.3, 14.3 to 51.3, and 23.0 to 51.3 branches per 15 cm row segments in summer, autumn, early winter, and late winter respectively. The average number of branches was the highest for AV10, Kaituna, SARDI GRAZER, and SF 714QL, high for Force 11, Haymaster 7, L55, and L90, and lowest for AV3, Gannong 4, and Qingshui from summer to late winter.

The herbage yield ranged from 2417.10 to 4304.58 kg/ha, 2211.66 to 4368.78 kg/ha, 61.69 to 1937.75 kg/ha, and 908.05 to 3020.43 kg/ha in summer, autumn, early winter, and late winter respectively (Table 4). Titan 7, Haymaster 7, Haymaster 9, and Cropper 9.5 had the highest and Qingshui the lowest herbage yields in individual seasons. The highest total DM yield was recorded from Haymaster 7 and WL925HQ, followed by Cropper 9.5, AV1001, Haymaster 9, SARDI 10 SERIES 2, SF 714QL, Titan 7 and Titan 9. The lowest total DM yield was recorded from Qingshui.

3.3. Nutritional qualities

There were significant differences ($P < 0.01$) in CP, CF, NDF, ADF, Ca, P, and RFV of leaf and stem among cultivars (Table 5). CP content ranged from 11.84 to 26.12% and 0.40 to 8.04% for leaf and stem respectively. AV09, Kaituna, AV1004, and SARDI 10 SERIES 2 had the highest CP and SF 714QL and SARDI 5 had the lowest CP in leaf. AV1005 had the highest CP and Force 10, Force 11, and Force 5 had the lowest CP in stem. CF content ranged from 2.18 to 6.69% and 0.61 to 4.10% for leaf and stem respectively. 54Q53 was the greatest and Haymaster 9 was the lowest in leaf CF content, whereas SARDI 5 was the highest and AV12 the lowest in stem CF content.

ADF content ranged from 19.93 to 26.96% and 33.48 to 43.23% for leaf and stem respectively. Kaituna was the highest and Stamina GT6 was the lowest in leaf ADF content. Tian 9 had the greatest and Gannong 4 had

Table 2. The comparison of leaf length (cm), leaf width (cm), and leaf area (10 leaves, cm^2) of lucerne cultivars in spring, summer, early winter, and late winter 2017.

	Summer			Autumn			Early winter			Late winter		
Variety	Leaf length	Leaf width	Leaf area	Leaf length	Leaf width	Leaf area	Leaf length	Leaf width	Leaf area	Leaf length	Leaf width	Leaf area
54Q53	2.0	0.9	11.65	1.8	1.0	9.73	1.7	1.7	13.90	1.9	1.4	15.40
57Q75	1.9	0.9	11.80	2.1	1.0	11.81	2.0	1.5	15.64	1.9	1.3	16.65
Cropper 9.5	2.3	0.9	13.99	2.0	0.8	9.78	2.5	1.7	21.66	2.1	1.5	19.75
AV1	2.1	1.0	13.08	1.9	1.0	10.25	1.6	1.1	10.95	2.1	1.1	17.22
AV2	1.8	0.9	12.81	1.8	0.9	8.91	0.8	0.7	6.42	1.3	1.0	15.24
AV3	2.0	1.0	14.06	1.5	1.0	9.57	1.2	0.6	6.37	1.5	1.0	12.22
Force 10	2.2	0.9	11.54	1.8	1.1	9.61	2.2	1.8	19.41	2.0	1.5	17.04
Force 11	1.9	0.9	11.87	1.8	0.7	11.06	2.2	1.5	19.59	2.1	1.3	16.89
Force 5	2.2	1.0	12.91	1.5	0.8	10.00	1.9	1.4	14.30	1.6	1.3	17.51
Force 7	2.1	0.8	12.59	1.8	0.9	10.59	2.1	1.4	17.17	1.8	1.4	16.95
Gannong 3	2.1	1.0	13.55	1.7	0.9	10.14	0.9	1.0	5.21	1.9	1.3	16.81
Gannong 4	2.0	0.8	15.11	1.8	0.9	11.34	0.8	0.7	4.39	2.0	1.2	13.90
Gannong 5	2.3	0.9	13.07	1.9	0.9	9.14	2.1	1.5	15.94	2.0	1.5	19.13
Gannong 6	1.9	0.9	13.80	1.8	1.0	12.75	1.0	1.0	7.17	1.7	1.3	14.56
Gannong 9	2.1	1.1	13.74	1.4	1.0	9.83	1.6	1.5	12.52	1.9	1.3	14.96
Haymaster 7	2.2	0.9	13.33	1.8	1.0	10.88	2.0	1.4	18.74	2.0	1.4	17.03
AV09	2.0	0.9	11.59	2.1	0.9	10.57	1.5	1.1	9.24	1.8	1.4	15.07
AV10	2.3	1.1	13.45	1.8	1.0	9.55	1.9	1.4	14.88	1.9	1.3	15.34
AV11	2.0	0.9	9.09	1.8	1.0	10.16	1.8	1.4	14.16	1.8	1.3	13.31
AV12	2.0	0.8	13.10	2.0	0.9	10.26	1.6	1.1	13.75	1.7	1.2	12.75
AV13	2.0	0.8	13.66	1.9	0.9	11.04	1.8	1.1	6.74	2.0	1.3	14.60
AV14	2.0	1.0	11.36	2.1	1.0	9.71	1.6	1.5	11.42	1.7	1.1	13.80
Kaituna	2.2	1.0	13.49	1.9	0.9	10.52	2.0	1.4	16.41	1.8	1.2	14.07
KI Creeper	1.8	0.8	12.59	2.0	1.0	12.03	0.6	0.8	5.59	2.1	1.1	15.37
L34HQ	1.8	1.0	12.24	1.7	0.9	9.86	1.3	1.1	9.41	1.7	1.4	13.51
L55	2.2	0.9	14.11	1.6	0.8	10.03	2.0	1.5	18.27	2.0	1.4	16.27
L90	2.2	0.9	13.75	2.0	0.9	8.56	2.3	1.5	17.93	1.7	1.2	13.51
AV1001	2.4	0.8	12.54	2.2	0.9	13.45	2.4	1.6	22.65	2.2	1.5	18.06
AV1002	2.3	1.0	11.35	2.0	0.9	9.59	2.0	1.3	16.86	2.0	1.6	16.74
Titan 5	2.0	0.8	13.69	1.8	0.9	10.67	1.7	1.3	14.37	1.8	1.3	16.83
Haymaster 9	2.2	0.8	12.67	1.9	1.0	10.28	2.4	1.6	20.82	2.0	1.6	20.18
AV1003	2.2	0.8	11.22	1.9	0.8	11.47	1.9	1.4	13.70	1.9	1.2	13.92
AV1004	2.3	0.9	13.47	1.8	1.0	9.57	1.9	1.4	16.97	2.1	1.3	16.23
AV1005	2.3	1.0	12.20	1.8	1.0	10.36	2.0	1.5	16.81	2.0	1.3	15.44
Qingshui	1.3	0.6	12.45	1.4	0.8	5.77	0.7	0.7	3.98	1.7	1.1	11.62
SARDI 10 SERIES 2	2.3	0.9	13.04	1.8	1.1	10.34	2.3	1.6	19.53	2.0	1.4	19.39
SARDI 5	1.9	0.9	11.19	1.8	1.0	10.69	1.6	1.1	14.48	2.0	1.4	15.80
SARDI 7	2.3	0.9	11.29	2.1	0.8	9.37	1.9	1.5	17.94	1.8	1.3	15.94
SARDI 7 SERIES 2	2.1	1.0	13.44	1.7	0.9	9.20	2.1	1.5	17.99	1.9	1.3	14.06
SARDI AT7	2.2	1.0	12.99	1.9	1.0	10.07	2.1	1.7	18.22	2.0	1.3	14.10
SARDI GRAZER	2.2	0.9	13.46	1.6	0.9	10.51	1.9	1.5	13.88	1.7	1.2	13.99
SF 714QL	2.0	0.9	14.15	2.0	0.8	10.39	2.2	1.6	20.03	2.1	1.4	17.61
Stamina 5	2.4	1.0	12.06	1.6	1.0	8.75	2.1	1.5	14.58	2.0	1.3	14.60
Stamina GT6	2.2	1.0	11.70	1.9	1.0	10.48	1.7	1.1	13.08	1.9	1.3	15.49
Titan 7	2.2	1.0	10.35	1.8	0.9	9.94	2.0	1.4	14.70	2.1	1.3	15.71
Titan 9	2.4	1.0	13.80	1.9	0.9	8.81	2.5	1.7	23.48	2.2	1.4	19.19
WL925HQ	2.3	1.0	13.35	1.7	1.0	12.18	2.0	1.5	18.29	2.2	1.5	18.17
S.E.M.	0.147**	0.092**	0.968**	0.159**	0.131	0.744**	0.149**	0.097**	1.206**	0.167**	0.108**	1.443**

**$P < 0.01$; *$P < 0.05$.

Table 3. The comparison of plant height (cm), leaf/stem ratio, branch number (branches/15 cm row segments) of lucerne cultivars in spring, summer, early winter, and late winter 2017.

	Summer			Autumn			Early winter			Late winter		
Variety	Plant height	Leaf/ stem	Branch Num.	Plant height	Leaf/ stem	Branch Num	Plant height	Leaf/ stem	Branch Num	Plant height	Leaf/ stem	Branch Num.
54Q53	39.9	1.56	30.3	22.3	3.66	43.3	13.2	–	42.3	21.0	4.12	38.7
57Q75	40.0	1.82	34.0	23.3	2.52	33.7	15.8	8.00	40.3	18.5	3.92	34.3
Cropper 9.5	47.0	1.21	31.5	28.9	2.66	36.3	21.2	3.43	37.7	28.6	3.28	40.7
AV1	41.4	1.42	34.5	26.3	3.12	37.0	9.5	–	24.7	18.6	4.04	35.3
AV2	33.5	1.88	45.3	21.3	2.85	37.7	9.3	–	25.3	19.0	6.63	40.0
AV3	34.8	1.95	25.5	13.5	4.10	21.7	3.8	–	17.0	14.1	4.84	26.7
Force 10	44.9	1.16	27.8	32.5	2.11	35.0	18.2	4.99	33.7	22.4	4.03	23.0
Force 11	41.1	1.29	34.3	23.0	2.44	33.7	19.2	4.44	45.7	20.1	3.93	45.0
Force 5	41.0	1.46	31.3	17.5	3.54	30.7	13.8	8.23	34.0	17.1	3.73	42.3
Force 7	39.8	1.38	36.5	22.1	2.40	32.0	15.4	7.95	34.0	18.4	4.69	29.7
Gannong 3	31.4	2.13	34.5	12.0	6.52	24.7	3.7	–	17.0	12.1	6.33	40.0
Gannong 4	26.8	2.14	28.3	13.0	7.79	18.0	3.8	–	14.3	16.4	6.40	28.3
Gannong 5	38.1	1.27	37.8	30.0	2.15	30.7	16.8	5.62	32.3	25.5	4.06	48.0
Gannong 6	34.4	1.44	33.3	14.8	6.41	22.3	4.3	–	17.7	18.4	5.36	36.3
Gannong 9	34.1	1.81	39.8	19.5	4.67	26.7	7.5	–	25.0	21.4	4.17	37.0
Haymaster 7	44.0	1.13	38.0	27.5	2.25	41.3	18.3	5.28	31.3	21.3	2.81	46.3
AV09	35.9	1.65	33.0	22.9	3.34	29.0	8.5	–	28.3	19.6	4.97	43.00
AV10	42.8	1.38	35.5	23.8	2.56	37.0	12.9	9.46	37.0	19.8	5.39	51.3
AV11	40.4	1.71	43.8	24.8	3.08	28.0	13.5	11.58	30.3	17.8	4.53	39.0
AV12	37.3	1.81	26.8	22.3	2.56	27.7	11.8	–	25.7	16.9	6.07	41.3
AV13	35.4	2.05	30.0	22.5	2.13	42.0	10.0	–	22.0	19.4	5.22	45.3
AV14	40.8	1.69	32.3	23.5	1.99	29.0	10.8	7.13	22.3	17.9	4.94	35.0
Kaituna	40.3	1.30	40.0	23.8	2.38	39.0	19.3	9.72	43.7	20.8	5.87	38.0
KI Creeper	26.9	2.40	27.5	15.8	2.39	34.7	8.1	–	19.7	17.8	4.78	30.7
L34HQ	40.9	1.53	35.8	15.5	4.08	38.3	9.2	–	27.3	16.4	6.45	43.7
L55	37.1	1.42	39.3	25.5	2.28	38.7	14.1	10.60	32.7	18.1	4.17	47.7
L90	40.5	1.12	32.8	26.0	2.12	42.0	18.8	5.23	35.3	21.6	4.83	48.3
AV1001	44.3	0.91	27.0	30.4	2.42	23.3	20.3	3.70	34.3	21.6	3.84	25.3
AV1002	42.3	1.13	32.8	25.3	3.01	34.7	16.9	6.19	38.0	20.6	4.07	36.7
Titan 5	39.4	1.33	32.5	18.4	2.62	32.7	12.7	7.98	30.3	18.0	4.67	38.3
Haymaster 9	43.6	1.22	32.8	29.6	1.87	33.3	21.1	3.93	40.7	25.5	2.52	32.7
AV1003	40.6	1.34	31.5	26.4	2.92	26.0	17.5	6.85	34.3	24.9	3.42	32.0
AV1004	36.9	1.46	34.3	21.8c	3.22	39.0	16.0	9.50	44.0	22.0	3.55	36.3
AV1005	39.6	1.35	30.5	24.3	3.32	38.7	12.8	13.88	41.7	20.6	4.02	41.0
Qingshui	23.6	3.00	19.5	16.0	4.26	27.7	3.7	–	14.7	14.6	7.19	28.7
SARDI 10 SERIES 2	45.3	1.20	38.3	24.9	2.64	38.0	22.3	3.97	31.3	25.9	4.14	34.7
SARDI 5	38.9	1.32	39.8	26.0	3.08	33.7	13.2	–	36.7	18.4	4.04	43.3
SARDI 7	36.9	1.49	30.8	23.8	3.01	49.3	16.8	7.01	37.0	20.6	3.83	36.0
SARDI 7 SERIES 2	38.8	1.27	29.8	18.5	3.63	33.7	14.6	7.48	34.0	26.5	3.35	47.3
SARDI AT7	36.6	1.25	30.3	25.5	2.96	24.7	15.3	6.42	35.3	17.1	4.68	39.0
SARDI GRAZER	37.3	1.45	34.3	24.4	2.74	41.7	16.1	9.26	51.3	19.4	5.92	40.7
SF 714QL	39.9	1.52	36.8	28.8	2.26	47.7	21.2	3.61	51.3	24.5	3.30	43.0
Stamina 5	35.1	1.15	38.0	20.3	3.28	35.0	12.2	9.01	27.3	21.1	4.91	37.3
Stamina GT6	39.1	1.30	33.8	21.0	2.12	38.0	16.0	9.35	50.3	23.8	3.89	30.0
Titan 7	44.3	1.33	36.0	25.0	2.32	31.7	15.6	9.01	39.0	17.5	5.40	39.3
Titan 9	45.1	1.25	33.5	34.0	1.32	25.7	17.8	3.81	37.7	25.0	3.95	31.3
WL925HQ	39.1	1.08	28.8	28.4	2.07	33.0	21.8	4.58	31.3	25.1	2.81	27.3
S.E.M.	2.224**	0.183**	4.024**	2.635**	0.308**	4.384**	1.144**	0.677**	4.615**	1.886**	0.455**	2.796**

$^{**}P < 0.01$; $^{*}P < 0.05$. – no stem component found.

the lowest ADF content in stem. NDF content ranged from 25.44 to 30.71% and 40.03 to 44.33% for leaf and stem, respectively, and was the lowest for L90 in leaf and AV12 in stem. RFV ranged from 207.25 to 252.66% and 120.01 to 142.22% for leaf and stem respectively. Force 10 had higher RFV than the rest of lucerne cultivars in leaf, while AV12 had higher RFV than the rest of lucerne cultivars in stem.

Ca content ranged from 1.48 to 2.90% and 0.40 to 1.01% for leaf and stem respectively. Kaituna had the highest Ca content. P content ranged from 0.06 to 0.18% and 0.01 to 0.07% for leaf and stem, respectively, and was the greatest for AV1 and AV14.

On average, the CP, CF, NDF, ADF, Ca, P, and RFV were 19.95, 4.41, 28.38, 23.99, 2.20, 0.11, and 230.80% in leaf, and were 3.57, 2.22, 42.28, 39.31, 0.73, 0.03, and 128.35% in stem, respectively. CP, CF, Ca, P, and RFV were significantly ($P < 0.01$) greater in leaf than in stem, whereas ADF and NDF were significantly ($P < 0.01$) lower in leaf than in stem.

Table 4. The comparison of herbage yield (kg/ha) of lucerne cultivars in spring, summer, early winter, and late winter 2017.

Variety	17 January 2017	27 February 2017	26 April 2017	5 June 2017	16 August 2017	Total herbage yield
54Q53	4111.98	4137.66	652.59	652.59	1988.80	11,543.62
57Q75	4163.34	3906.54	1126.07	1396.63	2185.30	12,777.88
Cropper 9.5	3701.10	4060.62	1464.27	1734.83	3020.43	13,981.25
AV1	4214.70	4137.66	990.79	652.59	1988.80	11,984.54
AV2	3957.90	3290.22	584.95	517.31	1939.68	10,290.06
AV3	3701.10	2982.06	449.67	449.67	1399.30	8981.80
Force 10	3957.90	4137.66	1193.71	1599.55	2578.30	13,467.12
Force 11	4009.26	4060.62	1126.07	1396.63	2676.55	13,269.13
Force 5	4266.06	3983.58	923.15	855.51	2185.30	12,213.60
Force 7	4060.62	3983.58	923.15	1261.35	2332.68	12,561.38
Gannong 3	3855.18	3290.22	382.03	382.03	1595.80	9505.26
Gannong 4	3495.66	2905.02	314.39	123.38	1301.05	8139.50
Gannong 5	4111.98	4214.70	1126.07	1396.63	2480.05	13,329.43
Gannong 6	3752.46	3290.22	517.31	320.34	1399.30	9279.63
Gannong 9	3803.82	3598.38	584.95	584.95	2037.93	10,610.03
Haymaster 7	4163.34	4368.78	1261.35	1667.19	2725.68	14,186.34
AV09	3752.46	3290.22	517.31	517.31	1399.30	9476.60
AV10	3855.18	3906.54	855.51	855.51	1939.68	11,412.42
AV11	3906.54	3521.34	517.31	584.95	1939.68	10,469.82
AV12	3547.02	3213.18	652.59	517.31	1595.80	9525.90
AV13	3701.10	3367.26	652.59	584.95	1595.80	9901.70
AV14	3649.74	3290.22	855.51	584.95	1890.55	10,270.97
Kaituna	4214.70	4060.62	855.51	889.33	2381.80	12,401.96
KI Creeper	3341.58	3059.10	517.31	517.31	1350.18	8785.48
L34HQ	4163.34	3829.50	720.23	584.95	1644.93	10,942.95
L55	4009.26	3906.54	787.87	1058.43	2037.93	11,800.03
L90	4060.62	4291.74	1058.43	1464.27	2578.30	13,453.36
AV1001	3547.02	4291.74	1802.47	1531.91	2529.18	13,702.32
AV1002	3718.22	4060.62	1148.62	1509.36	2512.80	12,949.62
Titan 5	4009.26	3675.42	720.23	1126.07	1988.80	11,519.78
Haymaster 9	3649.74	4137.66	1464.27	1937.75	2676.55	13,865.97
AV1003	3957.90	3906.54	923.15	1193.71	2774.80	12,756.10
AV1004	3957.90	3675.42	923.15	1126.07	2430.93	12,113.47
AV1005	3957.90	3752.46	990.79	1058.43	2283.55	12,043.13
Qingshui	2622.54	2211.66	123.38	61.69	908.05	5927.31
SARDI 10 SERIES 2	3855.18	4060.62	1058.43	1802.47	3118.68	13,895.38
SARDI 5	4009.26	4137.66	923.15	990.79	2283.55	12,344.41
SARDI 7	3752.46	3752.46	1058.43	1396.63	2725.68	12,685.66
SARDI 7 SERIES 2	3855.18	3829.50	720.23	1193.71	2480.05	12,078.67
SARDI AT7	4111.98	3983.58	1058.43	1193.71	2087.05	12,434.75
SARDI GRAZER	4163.34	3675.42	855.51	855.51	2234.43	11,784.21
SF 714QL	3547.02	4137.66	1396.63	1734.83	2823.93	13,640.07
Stamina 5	3701.10	3521.34	787.87	923.15	2087.05	11,020.51
Stamina GT6	4317.42	4137.66	990.79	1193.71	2136.18	12,775.76
Titan 7	4317.42	4291.74	1261.35	1464.27	2283.55	13,618.33
Titan 9	3702.46	4137.66	1464.27	1599.55	2676.55	13,580.49
WL925HQ	4111.98	4214.70	1261.35	1734.83	2774.80	14,097.66
S.E.M.	84.333**	92.648**	87.772**	88.679**	90.794**	236.848**

**$P < 0.01$; *$P < 0.05$.

3.4. Correlation between morphological, production, and nutritive characteristics

Significant correlations ($P < 0.05$) were detected for a number of measured parameters (Table 6). CP had a positive correlation with leaf-stem ratio, but a negative correlation with herbage yield, plant height, leaf area, and leaf length. Herbage yield was positively correlated with plant height, Ca content, number of branches, leaf area, leaf length, and leaf width. Plant height was positively correlated with Ca content, leaf area, number of branches, leaf length, and leaf width. ADF content was negatively correlated with number of branches and RFV. NDF content was negatively correlated with RFV. Ca content had a positive correlation with leaf area and leaf length. Leaf area had a positive correlation with the number of branches, leaf length and leaf width. Number of branches was positively correlated with leaf length, leaf width and RFV. Leaf length had a positive correlation with leaf width.

3.5. Grey relationship analysis

Table 7 shows that, based on grey relational analysis, the 10 cultivars/lines that had highest production and quality performance were: Cropper 9.5, SARDI 10 SERIES 2, Haymaster 9, Titan 9, SF 714QL, Kaituna, Haymaster 7, AV1001, AV1002, and WL925HQ. The 10 cultivars/lines that had higher production and quality performance were: Force 10, Force 11, AV1005, Force 7, AV1, 54Q53, L90, SARDI AT7, Gannong 5,

Table 5. The comparison of crude protein (CP, %), crude fat (CF, %), neutral detergent fiber (NDF, %), acid detergent fiber (ADF, %), calcium (Ca, %), phosphorous (P, %), and relative feed value (RFV, %) of lucerne.

	CP		CF		NDF		ADF		RFV		Ca		P	
Variety	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
54Q53	19.51	3.09	6.69	1.76	29.18	42.15	23.78	38.90	129.39	224.73	2.29	0.51	0.14	0.03
57Q75	20.33	1.24	4.11	1.82	27.91	42.90	25.12	38.94	126.99	231.45	2.19	0.97	0.14	0.03
Cropper 9.5	16.96	2.67	4.78	1.41	28.03	42.47	24.27	38.52	129.09	232.58	2.69	0.85	0.14	0.04
AV1	20.80	1.37	4.58	2.63	27.38	42.39	25.08	40.35	126.11	236.02	2.22	0.81	0.18	0.04
AV2	21.12	1.08	4.63	3.89	26.91	42.81	23.59	38.69	127.85	243.92	1.97	0.86	0.15	0.04
AV3	20.47	2.72	3.86	2.33	29.99	42.53	25.88	38.27	129.27	213.33	2.05	0.77	0.06	0.05
Force 10	18.97	0.64	5.40	1.54	27.95	42.49	24.32	38.36	129.23	233.01	1.96	0.57	0.13	0.04
Force 11	19.80	0.40	4.80	1.36	25.99	41.13	23.50	38.59	133.28	252.66	2.43	0.76	0.14	0.03
Force 5	22.05	0.51	5.06	2.97	28.70	42.34	22.97	38.99	128.74	230.23	2.03	0.84	0.16	0.04
Force 7	22.04	3.91	4.91	3.06	27.88	44.33	23.84	39.66	121.79	234.71	2.60	0.70	0.07	0.01
Gannong 3	22.86	4.96	4.15	1.75	29.20	41.90	25.74	38.70	130.55	219.58	2.35	0.44	0.09	0.06
Gannong 4	23.26	3.54	3.49	2.70	29.34	43.90	25.19	33.48	133.16	219.76	2.08	0.86	0.14	0.05
Gannong 5	20.20	3.07	5.39	1.16	28.51	42.60	22.84	40.44	125.34	232.09	1.98	0.88	0.07	0.03
Gannong 6	21.03	4.80	5.33	2.54	28.38	41.96	24.70	37.62	132.13	228.60	1.84	0.88	0.15	0.06
Gannong 9	23.33	3.88	3.38	2.16	27.73	42.40	24.32	37.21	131.55	235.22	2.06	0.40	0.07	0.05
Haymaster 7	22.10	2.37	5.66	1.63	27.74	41.53	22.17	36.65	135.19	240.21	2.60	0.50	0.08	0.03
AV09	23.64	4.26	3.75	2.60	30.16	42.30	24.01	40.20	126.76	216.51	1.91	0.42	0.15	0.05
AV10	22.21	3.54	3.71	2.01	29.37	41.39	23.68	37.27	134.54	223.71	1.87	0.59	0.07	0.03
AV11	22.34	4.69	5.55	1.75	29.81	43.87	24.98	38.94	124.30	216.83	2.01	0.69	0.08	0.06
AV12	20.84	3.50	4.92	4.10	29.29	40.03	22.58	35.55	142.22	226.54	2.03	0.79	0.16	0.05
AV13	20.71	4.74	4.71	1.23	29.96	41.20	25.56	35.74	137.95	214.88	1.90	0.77	0.07	0.05
AV14	20.09	4.69	3.71	3.00	27.28	41.49	24.53	34.87	138.41	238.28	2.20	0.77	0.14	0.07
Kaituna	24.08	4.70	4.09	2.84	30.49	41.47	26.96	38.88	131.56	207.25	2.04	1.01	0.14	0.03
KI Creeper	19.46	4.51	4.44	3.06	28.52	42.19	25.25	38.44	130.12	226.12	1.48	0.70	0.14	0.02
L34HQ	23.06	3.21	5.68	1.42	28.22	41.88	23.25	37.23	133.12	233.48	2.06	0.51	0.13	0.02
L55	20.05	3.32	5.07	1.91	26.94	41.05	22.75	38.67	133.26	245.86	2.38	0.68	0.14	0.02
L90	17.89	2.15	4.14	1.50	25.44	42.85	23.66	39.81	125.69	257.78	2.27	0.63	0.14	0.01
AV1001	14.68	3.50	5.37	1.70	30.71	42.25	24.77	38.21	130.20	210.98	2.17	0.66	0.07	0.02
AV1002	21.21	3.01	4.01	3.45	28.23	42.40	23.16	40.62	125.65	233.89	2.46	0.76	0.12	0.03
Titan 5	20.46	4.24	2.47	1.82	27.98	42.34	22.29	38.82	128.90	238.15	2.90	0.70	0.06	0.04
Haymaster 9	20.42	5.94	2.18	2.03	28.06	42.73	24.69	36.96	130.93	230.92	2.60	0.90	0.11	0.05
AV1003	23.44	3.48	4.60	3.71	28.51	41.43	24.52	38.67	132.07	227.85	2.34	0.65	0.10	0.03
AV1004	24.88	3.18	3.57	1.62	27.18	42.51	23.77	42.29	122.46	240.92	2.19	0.80	0.06	0.03
AV1005	21.39	8.04	3.22	2.82	29.14	41.48	26.00	41.39	127.11	219.48	2.07	0.76	0.11	0.03
Qingshui	23.40	4.95	3.63	1.67	29.84	41.48	23.75	41.96	126.05	219.56	2.20	0.85	0.11	0.03
SARDI 10 SERIES 2	26.12	4.06	4.31	1.16	29.53	41.73	23.16	40.73	127.46	223.28	2.35	0.89	0.12	0.03
SARDI 5	11.84	4.24	4.91	0.61	28.36	43.00	23.94	42.30	121.02	230.40	2.32	0.80	0.12	0.03
SARDI 7	16.14	3.68	4.19	1.60	28.82	42.79	24.31	40.11	125.50	225.97	2.37	0.85	0.07	0.02
SARDI 7 SERIES 2	15.09	4.02	3.67	2.69	28.74	42.89	23.79	41.60	122.52	228.09	1.91	0.86	0.14	0.04
SARDI AT7	18.18	3.45	4.65	3.23	30.25	43.68	24.27	41.79	120.01	215.57	2.35	0.63	0.12	0.01
SARDI GRAZER	18.20	3.99	3.92	3.13	26.53	43.91	24.21	41.35	120.10	245.83	2.29	0.91	0.11	0.02
SF 714QL	11.87	4.06	4.27	2.40	26.25	42.74	23.61	42.57	121.46	249.86	2.35	0.84	0.10	0.03
Stamina 5	15.21	5.00	2.37	1.55	25.73	41.31	24.44	41.36	127.72	252.83	1.84	0.58	0.12	0.03
Stamina GT6	15.32	4.05	4.69	1.42	27.97	42.49	19.93	41.46	123.93	244.34	2.70	0.57	0.11	0.03
Titan 7	18.40	4.52	5.50	1.61	28.27	42.52	23.36	40.91	124.82	232.95	2.00	0.88	0.10	0.02
Titan 9	17.28	2.95	5.39	2.64	27.91	41.72	22.18	43.23	123.19	238.68	2.08	0.83	0.12	0.03
WL925HQ	14.73	3.64	4.24	3.19	29.67	42.04	22.97	42.40	123.65	222.74	2.37	0.51	0.10	0.01
S.E.M.	0.020**	0.005**	0.332**	0.215**	0.817*	0.903**	0.817**	0.769**	2.985**	7.057**	0.068**	0.055**	0.016**	0.002**

$^{**}P < 0.01$; $^{*}P < 0.05$.

Table 6. Correlation coefficients between morphological, yield and nutritive characteristics of lucerne cultivars – leaf-to-stem ratio (LSR), herbage yield (HY), plant height (PH), crude protein (CP), crude fat (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), calcium (Ca), phosphorous (P), leaf area (LA), number of branches (NB), leaf length (LL), leaf width (LW), and relative feed value (RFV).

Item	LSR	HY	PH	CP	CF	NDF	ADF	Ca	P	LA	NB	LL	LW	RFV
LSR	1.000													
HY	−0.036	1.000												
PH	−0.107	0.915**	1.000											
CP	0.300*	−0.442**	−0.382**	1.000										
CF	−0.146	0.021	0.047	−0.086	1.000									
NDF	0.163	0.159	0.125	−0.164	−0.145	1.000								
ADF	0.051	−0.169	−0.160	0.189	0.141	0.173	1.000							
Ca	0.067	0.437**	0.383**	−0.143	−0.173	0.008	−0.046	1.000						
P	−0.201	−0.255	−0.170	0.009	0.232	−0.176	−0.159	−0.087	1.000					
LA	−0.104	0.875**	0.852**	−0.381**	−0.029	0.100	−0.128	0.433**	−0.216	1.000				
NB	0.204	0.580**	0.528**	−0.229	−0.079	0.165	−0.361*	0.253	−0.138	0.412**	1.000			
LL	−0.017	0.865**	0.880**	−0.364*	−0.089	0.173	−0.143	0.307*	−0.259	0.877**	0.417**	1.000		
LW	0.027	0.756**	0.773**	−0.248	−0.114	0.109	−0.111	0.124	−0.162	0.742**	0.467**	0.762**	1.000	
RFV	−0.054	0.186	0.146	−0.241	−0.097	−0.414**	−0.912**	0.133	0.138	0.128	0.356*	0.101	0.100	1.000

$^{*}P < 0.05$; $^{**}P < 0.01$.

Table 7. Correlation degree and ranking of 47 lucerne cultivars based on a comprehensive grey correlation analyses on leaf/stem ratio (LSR), herbage yield (HY), plant height (PH), crude protein (CP), crude fat (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), calcium (Ca), phosphorous (P), leaf area (LA), number of branches (NB), leaf length (LL), leaf width (LW), and relative feed value (RFV). WGCD denotes weighted grey correlative degree, and WO denotes weighted order.

	Grey correlation coefficient															
Variety	LSR	HY	PH	CP	CF	NDF	ADF	Ca	P	LA	NB	LL	LW	RFV	Scores	WO
54Q53	0.348	0.627	0.572	0.555	0.831	0.899	0.817	0.582	0.595	0.566	0.698	0.615	0.874	0.791	0.672	16
57Q75	0.528	0.759	0.583	0.523	0.477	0.881	0.863	0.717	0.600	0.659	0.606	0.687	0.734	0.815	0.663	24
Cropper 9.5	0.371	0.956	1.000	0.472	0.499	0.871	0.821	0.944	0.618	0.932	0.632	0.923	0.874	0.833	0.771	1
AV1	0.335	0.668	0.568	0.541	0.609	0.848	0.915	0.661	1.000	0.579	0.542	0.659	0.628	0.835	0.674	15
AV2	0.386	0.533	0.480	0.542	0.849	0.846	0.805	0.593	0.666	0.472	0.647	0.446	0.492	0.895	0.619	38
AV3	0.377	0.460	0.398	0.575	0.500	0.943	0.866	0.588	0.391	0.460	0.389	0.494	0.514	0.736	0.552	47
Force 10	0.407	0.861	0.835	0.472	0.576	0.869	0.817	0.513	0.573	0.696	0.485	0.730	1.000	0.836	0.684	11
Force 11	0.403	0.829	0.639	0.486	0.497	0.773	0.799	0.729	0.603	0.741	0.735	0.694	0.656	1.000	0.681	12
Force 5	0.557	0.692	0.521	0.554	0.740	0.889	0.795	0.602	0.835	0.635	0.580	0.583	0.709	0.817	0.665	22
Force 7	0.534	0.732	0.567	0.691	0.730	0.931	0.844	0.787	0.340	0.689	0.546	0.667	0.727	0.804	0.676	14
Gannong 3	0.482	0.487	0.372	0.800	0.475	0.891	0.877	0.580	0.495	0.498	0.472	0.517	0.614	0.771	0.587	43
Gannong 4	0.531	0.423	0.374	0.737	0.500	0.971	0.707	0.630	0.714	0.487	0.384	0.514	0.510	0.785	0.585	44
Gannong 5	0.427	0.838	0.721	0.578	0.533	0.891	0.837	0.602	0.369	0.689	0.651	0.753	0.773	0.809	0.669	19
Gannong 6	0.430	0.475	0.422	0.685	0.711	0.866	0.806	0.562	0.937	0.531	0.447	0.504	0.597	0.827	0.626	36
Gannong 9	0.372	0.554	0.477	0.761	0.448	0.859	0.782	0.496	0.406	0.571	0.526	0.568	0.829	0.863	0.606	40
Haymaster 7	0.389	1.000	0.729	0.623	0.620	0.832	0.711	0.693	0.376	0.756	0.720	0.708	0.767	0.920	0.698	7
AV09	0.359	0.485	0.503	0.806	0.514	0.940	0.869	0.470	0.721	0.508	0.552	0.603	0.623	0.739	0.621	37
AV10	0.651	0.615	0.597	0.681	0.461	0.880	0.766	0.495	0.368	0.608	0.757	0.670	0.804	0.814	0.632	35
AV11	0.808	0.544	0.573	0.750	0.622	0.989	0.859	0.555	0.450	0.511	0.598	0.615	0.731	0.729	0.637	33
AV12	0.368	0.488	0.512	0.618	1.000	0.834	0.695	0.588	0.863	0.553	0.494	0.603	0.570	0.875	0.649	27
AV13	0.349	0.509	0.506	0.666	0.478	0.893	0.776	0.546	0.408	0.502	0.587	0.638	0.581	0.785	0.590	42
AV14	0.509	0.531	0.546	0.636	0.549	0.818	0.725	0.641	0.883	0.506	0.482	0.600	0.740	0.929	0.644	30
Kaituna	0.682	0.713	0.646	0.871	0.575	0.922	0.931	0.668	0.614	0.631	0.756	0.666	0.709	0.719	0.698	6
KI Creeper	0.352	0.451	0.407	0.604	0.650	0.878	0.851	0.443	0.535	0.497	0.458	0.514	0.512	0.803	0.567	45
L34HQ	0.402	0.578	0.474	0.707	0.595	0.858	0.753	0.521	0.496	0.490	0.624	0.511	0.637	0.862	0.605	41
L55	0.633	0.650	0.561	0.581	0.581	0.796	0.779	0.675	0.555	0.722	0.732	0.681	0.722	0.947	0.668	20
L90	0.432	0.858	0.678	0.482	0.455	0.804	0.843	0.612	0.511	0.617	0.733	0.747	0.727	0.980	0.669	17
AV1001	0.376	0.902	0.812	0.440	0.592	0.960	0.827	0.595	0.357	1.000	0.449	1.000	0.791	0.730	0.694	8
AV1002	0.464	0.782	0.656	0.613	0.644	0.875	0.854	0.743	0.508	0.632	0.604	0.753	0.778	0.821	0.689	9
Titan 5	0.542	0.625	0.514	0.633	0.374	0.865	0.770	1.000	0.360	0.652	0.555	0.599	0.660	0.865	0.642	32
Haymaster 9	0.351	0.933	0.871	0.712	0.370	0.881	0.786	0.917	0.523	0.883	0.587	0.805	0.858	0.834	0.741	3
AV1003	0.468	0.756	0.707	0.744	0.798	0.853	0.834	0.649	0.441	0.560	0.505	0.678	0.622	0.823	0.665	21
AV1004	0.593	0.682	0.575	0.817	0.424	0.845	0.940	0.644	0.335	0.666	0.690	0.733	0.734	0.843	0.661	25
AV1005	1.000	0.674	0.581	0.927	0.486	0.875	1.000	0.592	0.464	0.637	0.675	0.717	0.795	0.754	0.678	13
Qingshui	0.465	0.350	0.367	0.838	0.432	0.899	0.926	0.670	0.463	0.388	0.388	0.412	0.431	0.750	0.555	46
SARDI 10 SERIES 2	0.399	0.938	0.843	1.000	0.443	0.896	0.858	0.753	0.507	0.826	0.605	0.775	0.903	0.774	0.747	2
SARDI 5	0.333	0.707	0.573	0.401	0.446	0.900	0.948	0.699	0.512	0.589	0.688	0.609	0.659	0.778	0.636	34
SARDI 7	0.494	0.747	0.588	0.477	0.466	0.909	0.877	0.747	0.348	0.632	0.685	0.715	0.698	0.778	0.647	29
SARDI 7 SERIES 2	0.507	0.678	0.590	0.460	0.515	0.910	0.913	0.574	0.604	0.635	0.622	0.667	0.772	0.774	0.647	28
SARDI AT7	0.500	0.717	0.559	0.525	0.711	1.000	0.940	0.641	0.426	0.648	0.530	0.733	0.859	0.706	0.669	18
SARDI GRAZER	0.693	0.649	0.579	0.542	0.588	0.869	0.920	0.737	0.432	0.584	0.838	0.611	0.682	0.858	0.665	23
SF 714QL	0.366	0.890	0.776	0.399	0.545	0.824	0.945	0.727	0.438	0.822	1.000	0.764	0.784	0.892	0.724	5
Stamina 5	0.634	0.584	0.515	0.487	0.356	0.771	0.930	0.489	0.478	0.555	0.577	0.706	0.794	0.957	0.608	39
Stamina GT6	0.545	0.759	0.604	0.466	0.492	0.870	0.778	0.770	0.448	0.567	0.677	0.643	0.649	0.872	0.644	31
Titan 7	0.606	0.887	0.628	0.565	0.596	0.881	0.871	0.606	0.417	0.566	0.631	0.707	0.724	0.811	0.657	26
Titan 9	0.363	0.880	0.914	0.487	0.740	0.843	0.914	0.617	0.497	0.936	0.525	0.907	0.859	0.834	0.730	4
WL925HQ	0.375	0.980	0.777	0.444	0.640	0.913	0.912	0.608	0.373	0.815	0.489	0.752	0.896	0.753	0.688	10
WGCD	0.479	0.690	0.602	0.616	0.569	0.879	0.844	0.644	0.529	0.632	0.599	0.664	0.715	0.824		
Weight	0.054	0.078	0.068	0.070	0.065	0.100	0.096	0.073	0.060	0.072	0.068	0.075	0.081	0.094		

and L55. The 10 cultivars/lines that had lowest production and quality performance were: AV2, Stamina 5, Gannong 9, L34HQ, AV13, Gannong 3, Gannong 4, KI Creeper, Qingshui, and AV3.

4. Discussion

4.1. Production characteristics

Lucerne populations can vary in a range of traits, the greatest differences usually being in traits such as winter-dormancy, plant height and herbage yield (Lorenzetti, Ceccarelli & Catena, 1972). The significant cultivar differences in herbage yield observed in the present study concurs with previous reports (e.g. Geleti, Hailemariam, Mengistu & Tolera, 2014; Monirifar, 2011). The lower total herbage yield of AV3, Gannong 3, Gannong 4, Gannong 6, AV09, AV12, AV13, KI Creeper, and Qingshui were probably attributed to varietal differences, primarily their growth behavior and winter dormancy. Some of these varieties such as Qingshui may have a place in mixed farming systems given their low production and prostrate growth behavior to reduce competition with companion species (Nie et al., 2016).

Significant decreases in the plant height in late autumn and winter in response to decreasing photoperiods and lower temperatures are an indication of 'winter-dormancy' (Boschma & Williams, 2008). In northern hemisphere, true expression of winter-dormancy aids survival during extreme winter conditions. In temperate Australia, extreme winter conditions rarely exist, and winter-dormancy can be determined by growth rate in either late autumn or winter. The significant varietal differences observed for plant height in the present study was in agreement with previous reports (e.g. Altinok & Karakaya, 2002), and plant height was highly correlated with herbage yield, which revealed that Haymaster 7, WL925HQ, Cropper 9.5, AV1001, Haymaster 9, SARDI 10 SERIES 2, SF 714QL, Titan 7, and Titan 9 were highly winter-active cultivars with greater rates of regrowth in winter. Winter-active species/cultivars are desirable for filling the feed gap of grazing systems over the winter months in temperate Australia (Smith et al., 2017).

Leaf-to-stem ratio is an important trait in the selection of appropriate forage cultivar as it is strongly related to forage quality (Juan, Shedder, Barnes, Swanson & Halgerson, 1993; Julier, Huyghe & Ecalle, 2000; Kratchunov & Naydenov, 1995). The significant cultivar differences in leaf-to-stem ratio observed in the present study is in line with the findings of Heidarian and Mostafavi (2012) and Lamb, Sheaffer and Samac (2003). Among the cultivars evaluated, 54Q53, AV1, AV13, KI Creeper, Haymaster 9, and SARDI 5 had inferior leaf-to-stem ratio, which could have been attributed to their distinctly greater plant height as plant height and stem proportion are correlated positively (Geleti et al., 2014). Leaf-to-stem ratio varied with seasons, i.e. early winter > late winter > autumn > summer, which could have resulted from shorter stem internodes and more leaves of lucerne under low temperature and short day length in autumn, early winter, and late winter than in summer. Lucerne cultivars begin to regrow in autumn, grow slowly in early – late winter, and enter reproduction with rapid stem development in late spring and summer (Liu, Liu & Yang, 2015). Therefore, leaf-to-stem ratio for lucerne was the lowest in summer.

4.2. Nutritive value

High quality lucerne was reported to contain >19% CP, <31% ADF, <40% NDF, and >155% RFV (Ball, Ray, Glover & Townsed, 1997; Kazemi, Tahmasbi, Naserian, Valizadeh & Moheghi, 2012). CP in lucerne helps to meet animals' protein needs. NDF and ADF represent highly indigestible and partially digestible plant material in feed (Hopper, Peterson & Burton, 2004). RFV is a calculated value that measures forage quality in terms of potential dry matter in take. In this study, CP content of all the cultivars ranged from 8% to 15%, which was below 19%. NDF content of all the cultivars ranged from 34% to 37%, below 40%. On the other hand, ADF content of all the cultivars ranged from 29% to 34%, of which most cultivars had over 31% ADF. RFV of all the cultivars ranged from 167.79% to 192.97%, well above 155%, so these lucerne varieties (or lines) can be cited in prime quality standard (high quality). The content of minerals in lucerne fully meets the livestock requirements. Significant differences were registered in the contents of CP, CF, ADF and NDF that were caused by genetic factors (Katić et al., 2009). Leaves accumulated high contents of CP, CF, RFV, Ca and P, and ADF and NDF contents were significantly lower in lucerne leaves than in stems, which were in line with the findings of Milić et al. (2011).

5. Conclusion

Significant differences existed among 47 lucerne cultivars in morphological and production characteristics, and nutritive values in temperate Australia. Leaves accumulated high contents of CP, CF, Ca and P, and had high RFV. Also, ADF and NDF were significantly lower in leaves than in stems. Cropper 9.5, SARDI 10 SERIES 2, Haymaster 9, Titan 9, SF 714QL, Kaituna, Haymaster 7, AV1001, AV1002, and WL925HQ were the best performers in temperate Australia, based on comprehensive grey correlation analysis. Further examination of these cultivars over multiple years is necessary to fully understand their superior traits for plant breeding and management of these cultivars.

Disclosure statement

No potential conflict of interest was reported by the authors.

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