Summary  Poor adaptation of numerous annual and perennial legumes across south eastern Australia due to acidic soils, insufficient rainfall resulting in false breaks, high input costs, soil acidification and the emergence of herbicide resistant weeds have resulted in limited options for producers seeking to establish productive pastures in the Riverina region of New South Wales (NSW). To overcome these challenges, numerous novel pasture species have been selected and recently released for establishment. However, limited knowledge exists regarding their ability to suppress weeds during establishment and in subsequent years when they regenerate. Field trials were conducted at Wagga Wagga, NSW over a 2 year period to evaluate: (a) the suppressive potential of eight selected pasture legumes against annual weeds; and (b) the impact of autumn (March) and winter (June) sowing dates on stand establishment. Weed and crop cover and biomass were assessed each year in replicated trials in 2016–2017. Results suggested that species mixtures with more than one pasture species were not significantly different (P<0.05) in terms of establishment and subsequent weed infestation. However, autumn sowing of arrowleaf clover, yellow serradella cv. Avila and French serradella/bladder clover generally resulted in increased (P<0.05) pasture crop cover over two growing seasons. Arrowleaf clover and biserrula cv. Casbah were strong performers and produced significantly greater crop biomass and also less weed biomass. However, weed suppression and subsequent biomass was not always related to competition for resources and production of total crop biomass. This was the case for yellow serradella cv. Santorini in both 2016 and 2017 where weed biomass was significantly reduced but total crop biomass produced was limited. This suggested that factors other than resource competition, such as allelopathy, were associated with weed suppression. Arrowleaf clover, biserrula cv. Casbah and yellow serradella cv. Santorini were generally the best and most reliable annual legumes with respect to yearly regeneration and pasture weed suppression in the Riverina.

Keywords Hard-seeded legume, weed suppression, competition, establishment.

INTRODUCTION
Pasture legumes have been an integral part of mixed farming systems in southeastern Australia as they provide high-quality nutrition for livestock and improve soil fertility due to their ability to fix atmospheric nitrogen. The selective use of pasture legumes has also been instrumental in effectively managing weeds in such rotational cropping systems (Mengel et al. 2001, Loi et al. 2005a, Loi et al. 2005b). Traditionally, subterranean clover has been the most widely used pasture in southern Australia but unpredictable weather patterns resulting in lower and inconsistent spring rainfall, high cost of legume establishment and low persistence mainly due to low hardseed levels have impacted on the suitability of subterranean clover in the region (Loi et al. 2001, Loi et al. 2005a).

To overcome these challenges, numerous novel self-regenerating annual pasture legumes including Biserrula pelecinus L. (biserrula), Ornithopus sativus Brot. (French serradella), Ornithopus compressus L. (yellow serradella), Trifolium glanduliferum Boiss. (gland clover), Trifolium spumosum L. (bladder clover) and Trifolium vesiculosum Savi. (arrowleaf clover) have been recently released in New South Wales (NSW). These pasture legumes are well adapted to the south eastern region, due to their successful establishment in diverse soils, drought tolerance, higher herbage production and nutritional quality relative to traditional pasture species. However, limited knowledge exists regarding their establishment following initial seeding and in subsequent years of regeneration. To maximise the adoption of introduced species/cultivars under suitable soil types and rainfall zones, further research is required in NSW to assess
the ability of selected pasture legumes to establish and produce improved yields while suppressing annual weeds to determine their suitability within sustainable cropping systems. Therefore, the objectives of this study were to evaluate: (a) the suppressive potential of selected annual pasture legumes against dominant annual weeds; and (b) the impact of sowing season; autumn (March) or winter (June) on establishment and regeneration of annual legumes in southeastern Australia.

MATERIALS AND METHODS
Field experiments were established in 2016 and 2017 at the Graham Centre field site and the Agricultural Research Institute field site in Wagga Wagga, NSW (35°S, 147°E). All experiments were arranged in a randomised complete block design with five replicates per treatment. The soil type was characterised as a fine red sodosol at both trial sites. Treatments were planted at standard sowing rates using a precision cone planter in 20 × 3 metre with 15 cm row spacing. All pasture treatments were sown on two different sowing dates either in the first week of March or first week of June and thereafter referred to as autumn and winter sowing dates respectively, except in the case of those not suitable agronomically for autumn sowing. All plots were fertilised with 100 kg ha⁻¹ of fertiliser (Croplift® 12, 1:2:1, Incitec Pivot, Victoria) at the time of sowing. The second trial site was established similarly in winter 2017 at the Wagga Wagga Agricultural Research Institute using only monoculture pasture treatments in 9 × 2 m plots with similar row spacing and seedling rates.

Percentage stand establishment of pasture crops and weeds was recorded using visual ratings on a scale of 0–100 performed at physiological maturity of the pasture crops when crops were at the flowering stage. In addition to qualitative data, two representative pasture samples were collected from each plot at a height of approximately 2 cm the soil surface (to simulate grazing by sheep) using 0.25 m² quadrants from monoculture plots to determine the total biomass of crop and weeds in 2016 and 2017. Plant matter was sorted into pasture legume and weed species. Overall, crop biomass of all treatments ranged from 44–90 g m⁻² while weed biomass ranged from 5–30 g m⁻² (Figure 1). Arrowleaf clover produced the highest crop biomass followed by biserrula cv. Casbah and gland clover, while cultivars of yellow serradella produced the least pasture ground cover. Arrowleaf clover initially exhibited the lowest percentage of weed infestation followed by biserrula cv. Casbah and yellow serradella cv. Santorini (Figure 1).

Generally, mean percentage crop cover was slightly to moderately higher for the autumn sowing date compared to winter sowing but the overall effect of sowing date was not significant (P>0.05) except for arrowleaf clover and both cultivars of yellow serradella. Biomass of pasture crops and weed species was also obtained in at crop maturity in 2016 and 2017 and these varied significantly (P<0.05) across pasture species. Overall, crop biomass of all treatments ranged from 44–90 g m⁻² while weed biomass ranged from 5–30 g m⁻² (Figure 1). Arrowleaf clover produced the highest crop biomass followed by biserrula cv. Casbah and gland clover. In contrast, yellow serradella cv. Santorini and subterranean clover produced the lowest crop biomass. Interestingly, arrowleaf clover had the lowest weed biomass followed by yellow serradella cv. Santorini. Remarkably, yellow serradella cv. Santorini produced the lowest biomass but also maintained low weed infestation.

A PLSR analysis was conducted to determine the relative effect of competitive traits on weed biomass. Competitive traits explained up to 30% of the variance in two latent factors when dataset from all species was analysed in one model suggesting a separate analysis for each species separately is appropriate. Overall, total weed biomass at physiological maturity was strongly correlated with crop biomass followed by LI.
Crop biomass appeared to have the strongest inverse effect on total weed biomass in the case of biserrula cv. Casbah, bladder clover, French serradella, subterranean clover and yellow serradella cv. Avila. In addition, LAI was observed to have a strong inverse effect on total weed biomass in the case of arrowleaf clover and gland clover. Clearly, crop biomass, NDVI and LAI were not associated with weed suppression in case of yellow serradella cv. Santorini.
RESULTS OF TWO YEARS OF SEVERAL FIELD TRIALS IN THE RIVERINA REGION OF NSW CLEARLY DEMONSTRATED SIGNIFICANT VARIATION IN THE COMPETITIVE ABILITY OF INDIVIDUAL PASTURE LEGUMES SPECIES AND CULTIVARS, RESULTING IN VARIABLE WEED SUPPRESSION AGAINST ANNUAL WEEDS. ARROWLEAF CLOVER, BISERRULA AND YELLOW SERRADELLA WERE GENERALLY THE MOST RELIABLE AND COMPETITIVE ANNUAL LEGUMES WITH RESPECT TO STAND ESTABLISHMENT, YEARLY REGENERATION AND CONSISTENT SUPPRESSION OF PASTURE WEED SPECIES IN TWO YEARS OF EXPERIMENTS PERFORMED AT MULTIPLE FIELD SITES IN WAGGA WAGGA. SOWING OF PASTURE LEGUMES IN AUTUMN OR WINTER IS FEASIBLE BUT CROPS PERFORMED MORE CONSISTENTLY WHEN SOWN IN JUNE. IN THIS STUDY AUTUMN SOWING DID NOT OFFER SIGNIFICANT ADVANTAGES COMPARED TO WINTER SOWING IN SUPPRESSING ANNUAL WEEDS. ARROWLEAF CLOVER AND BISERRULA HAVE BEEN REPORTED TO HAVE GREATER ABILITY TO SUCCESSFULLY REGENERATE IN MEDITERRANEAN-LIKE CLIMATIC CONDITIONS. IN GENERAL, THESE TWO LEGUMES PRODUCED SIGNIFICANTLY GREATER CROP BIOMASS, AND AS A RESULT, CONSIDERABLY LESS WEED BIOMASS DUE TO LOW LIGHT PENETRATION OF THE DENSE CROP CANOPY AND COMPETITION FOR RESOURCES. RESULTS OF PLSR ANALYSIS DEMONSTRATED THAT, IN GENERAL, CROP BIOMASS HAD THE STRONGEST INVERSE EFFECT ON TOTAL WEED BIOMASS FOR MANY PASTURE SPECIES AND LIKELY ALSO IMPACTED WEED SEED GERMINATION AND SEEDLING GROWTH. SEVERAL MECHANISMS COULD BE ASSOCIATED WITH THE ABILITY OF THESE PASTURE LEGUMES TO SUPPRESS WEEDS INCLUDING THEIR ABILITY TO RAPIDLY DEVELOP DENSE CANOPIES LIMITING LIGHT INTERCEPTION AT THE SOIL SURFACE. IN ADDITION, YELLOW SERRADELLA MAY EXHIBIT THE ABILITY TO SUPPRESS WEEDS THROUGH ALLELOPATHIC INTERFERENCE. ADDITIONAL INFORMATION RELATED TO THE MECHANISMS INVOLVED IN WEED SUPPRESSION, INCLUDING THE POTENTIAL FOR SOME SPECIES TO RELEASE ALLELOCHEMICALS OVER TIME, WILL BE USEFUL IN THE SELECTION OF NEW PASTURE SPECIES/CULTIVARS FOR SUSTAINABLE WEED MANAGEMENT SOLUTIONS, PARTICULARLY WHEN CONSIDERING THE INCREASING IMPORTANCE OF HERBICIDE RESISTANCE IN PASTURE WEEDS.

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