ALLELOPATHIC BEHAVIOUR OF GRAIN LEGUMES IN COTTON-BASED FARMING SYSTEMS

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Abstract

Cotton emergence, growth and lint yield were reduced and fibre quality degraded by sowing leguminous crops such as chickpea (*Cicer arietinum* L.) and faba bean (*Vicia Faba* L.) before cotton. Greatest inhibition of cotton occurred when seed material remained *in situ*. Germination studies using cold-water extracts of wheat (*Triticum aestivum* L.), chickpea, faba bean, cowpea (*Vigna unguiculata* Walp.), sorghum (*Sorghum bicolor* Moench.) and dolichos (*Lablab purpureus* L.) seed materials, and pot experiments using seed/soil mixtures of the same rotation crops showed that cotton germination, emergence, and growth were lower with legumes in comparison with cereals and the untreated control. Cotton growth reduction caused by cereal and leguminous rotation crop stubble were greater when incorporated compared with mulching. It is suggested that allelopathic effects of leguminous rotation crops could be reduced by green manuring the crops prior to seed formation.

Key words: Allelopathy, rotation crop, Vertisol, cotton, farming system, legume, irrigation.

Allelopathy is defined as the direct or indirect harmful or beneficial effects of one plant on another through production of chemical compunds that escape into the environment (6). Commonly, however, it is the harmful effects of these chemical compounds which are referred to as allelopathy. The impact of allelopathy in cotton (*Gossypium hirsutum* L.)-based farming systems in Australia has been little studied, although a significant body of research exists in the United States with respect to the allelopathic reduction of cotton emergence, vegetative and reproductive growth, and yield by leguminous cover crops (1, 2, 4, 7, 8). These data suggest that there is a strong interaction between soil-borne diseases and allelopathy in cotton-based cropping systems; and there is significant variation between different legume crops in allelopathic potential which is often modified by soil type.

In this paper we present data on allelopathic behaviour of grain legumes observed:

- initially in a field trial established since 1993 which has as its objective developing sustainable crop rotations and rotation-crop management strategies for irrigated cotton-based farming systems; and

- supplementary pot trials and germination studies established to confirm the allelopathic potential or otherwise of a number of commonly used rotation crops in cotton-based farming systems.

Materials and methods

Field observations

The trial was located on a commercial cotton farm, "Glenarvon", near Wee Waa in north-western New South Wales. The soil (55 g/100g clay, 18 g/100g silt and 27 g/100g sand in the surface 0.6 m) is a deep, uniform grey clay [grey, self-mulching, calcareous Vertosol (3)]. The cropping systems used in the trial were cotton followed by N fertilised wheat (urea at 140 kg N/ha in 1993; 120 kg N/ha thereafter), unfertilised wheat, unfertilised grain legumes (chickpea in 1993; faba bean thereafter at the co-operating cotton grower's suggestion) which were either harvested or the grain incorporated. The experimental design used was a randomised complete block with 4 replications. Individual plots consisted of 24 rows which were 400 m in length. The cropping systems reflect both currently used cropping systems in that locality and the local cotton growers' views with respect to some potentially useful crop sequences and management practices (*eg*. incorporating rather than harvesting legume grain). Land preparation consisted of minimum tillage with an aer-way cultivator and residue incorporation into the ridges. Cotton was fertilized with anhydrous ammonia at a rate of 120 kg N/ha. Cotton was sown at a density of 9 seeds/m in October 1994 and 13 seeds/m in October 1996. The cotton varieties sown were CS-50, which is susceptible to verticillium wilt, in 1994; and CS 8-S, which is resistant to verticillium wilt, in 1996. Commercial cropping practices (mechanized land preparation, chemical application and harvesting; aerial application of pesticides and defoliants *etc.*) used in local cotton production systems were followed, with all field operations being performed by the co-operating farmer. All crops in the cropping sequences were irrigated by furrow irrigation at a rate of 1 ML/ha. The effects of the rotation crops on cotton growth were monitored by evaluating stand density, boll numbers and weight, lint yield, and lint fibre quality. Disease incidence was evaluated by the plant pathology unit at the Australian Cotton Research Institute.

Germination studies

Seeds of cotton (cvv. CS-50 and Siokra 1-4) were germinated in petri dishes lined with filter paper (50 seeds per dish) to which 10 mL of cold-water extracts of crushed seeds of wheat (*Triticum aestivum* L.), chickpea (*Cicer arietinum* L.), faba bean (Vicia faba L.), cowpea (*Vigna unguiculata* Walp.), sorghum (*Sorghum bicolor* Moench.) and dolichos (*Lablab purpureus* L.), and a control treatment of de-ionized water had been added. Cold-water extracts were obtained by crushing the seeds, soaking 100 g of crushed seed (2 mm) in 200 mL of de-ionised water for 16 h, and filtering through a no. 42 Whatman filter paper (4). The experimental design was a randomised complete block with 4 replications. For the purpose of this study germination was defined as when the cotton radicle was 2 mm. Germination was evaluated at 2-3 day intervals from sowing until 20 days after sowing.

Pot Experiment 1

The experiment was conducted using 2 grey clays [soil from the previously described field site, Gn; and C1 (50 g/100 g clay, 23 g/100 g silt and 27 g/100 g sand) from the Australian Cotton Research Institute, Narrabri] and 2 cotton varieties (SIOKRA 1-4 and CS-50). One hundred grams of air-dried soil (2 mm, soil water content of 6.7 g/100 g) with which 12 g crushed rotation crop seed material (2 mm) had been mixed, were added to 0.45 L pots and compacted to an air-dry bulk density of 1.0 Mg/m^3. The rotation crops used in these pot experiments were wheat, chickpea, faba bean, cowpea, sorghum and dolichos. The experiments also included an untreated control treatment. Gravimetric water content of each pot was then made up to 30 g/100 g by adding de-ionised water. The pots were arranged in a randomised complete block design with 10 replications. Ten cotton seeds were sown into each pot and emerg-ence, and top dry matter and root length density at harvest were evaluated. Root length density was evaluated by washing the contents of each pot over a 0.2 mm sieve, separating the root material from other organic detritus and measuring root length with Newman's line intercept method (5).

Pot Experiment 2

The equivalent of 4 t/ha stubble from three cereals: sorghum, barley (*Hordeum vulgare* L.) and wheat; and seven legumes: dolichos cvv. Koala and Rongai, soy-bean (*Glycine max*), faba bean, cowpea, lupin (*Lupinus angustifolius*) and lucerne (*Medicago sativa*) was appl-ied as surface stubble or incorporated as ground mulch to pots filled with standard potting mix. Adequate nutrition was supplied to the plants via Aquasol? (N23:P4:K18 + trace elements). Ten pre-germinated cotton seeds (cv. Sicala V2) were established in each pot and plants harvested after 53 days (approximately 6 nodes). Plant height, number of nodes and dry weight measurements were recorded.

Results and discussion

Field observations

Lowest emergence and stand density of cotton occurred during 1994-95 growing season in plots where legume grain had been incorporated (Fig. 1). Emergence and stand density were lowest during 1996-97 growing season in all plots where legumes had been sown during the winter of 1995. The absence of any difference bet-ween the two legume treatments in 1996-97 may have been due to the significant seed drop caused by the high numbers of *Heliothis* moths which occurred during September 1995 in the legume/harvested treatment. In both cotton cropping seasons boll numbers were least where legume/grain incorporated preceded cotton (Fig. 2). Boll weight, which was measured only during 1996-97 was lower in both legume-cotton sequences. Mean boll weight/m2 on 24 February 1997 was 367.6 g with wheat-cotton and 265.8 g with legume-cotton (?SEM = 24.01; $P<0.05$). Cotton lint yields in 1994-95 and 1996-97 were higher, and fibre quality better where wheat had been sown prior to cotton (Table 1). Significant diseases incidence occurred only during the 1994-95 season when verticillium wilt (caused by *Verticillium dahliae*) was detected with the vascular discolouration technique in all treatments. Significant differences in verticilium wilt incidence did not occur between treatments and averaged 72%.

Germination studies and pot experiment 1

In general, reductions in germination, emergence, dry matter production and root length density of cotton seedlings were in the order of winter legumes (faba bean, chickpea)? summer legumes (dolichos, cowpea)? cereals (sorghum, wheat) and control (Table 2, Fig. 3). Furthermore, growth reduction of Siokra 1-4 appeared to be less than that of CS-50. These results confirm the field observations, in that cotton growth was most affected by the leguminous rotation crops. Hence, although the legumes can "fix" significant amount of nitrogen they can also reduce cotton yields, particularly if significant amounts of seed material are left in the field either due to incorporation or seed drop which in turn may be caused by harvest inefficiency or insect, disease or environmental stress.

Pot experiment 2

In comparison with surface application, incorporating mulch produced a significant ($P<0.05$) reduction in plant height (310 to 250 mm), number of nodes per plant (6.4 to 5.5) and dry weight (26 to 22 g/pot) although individual crop species did not cause any significant differences. The faster decomposition of crop residues due to incorporation may have resulted in a rapid release of allelopathic substances into the root zone, whereas with the slower decomposition of surface applied mulch this may not have occurred. The lack of difference between species also suggests that high concentrations of potentially allelopathic chemicals may not occur in stubble to the same extent as in seeds. Consequently green manuring a legume crop prior to seeding may be a? management option to avoid the allelopathic effects of the legume seeds in cotton-based rotations.

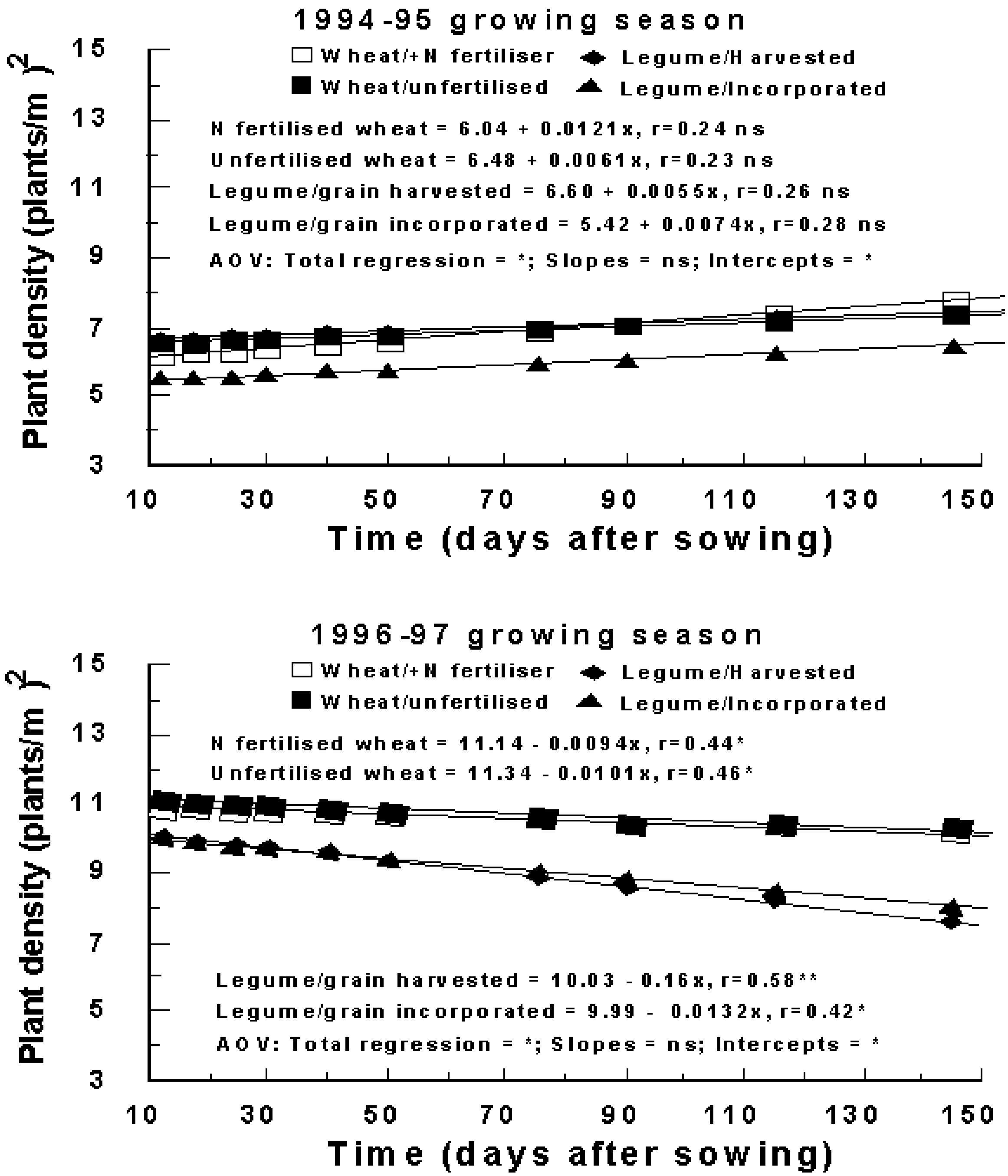
1994-95 growing season
Wheat/+N fertiliser
Legume/Harvested
Wheat/unfertilised
Legume/Incorporated
N fertilised wheat = 6.04 + 0.0121x, r=0.24 ns
Unfertilised wheat = 6.48 + 0.0061x, r=0.23 ns
Legume/grain harvested = 6.60 + 0.0055x, r=0.26 ns
Legume/grain incorporated = 5.42 + 0.0074x, r=0.28 ns
AOV: Total regression = *; Slopes = ns; Intercepts = *
Plant density (plants/m)2
Time (days after sowing)
1996-97 growing season
Wheat/+N fertiliser
Legume/Harvested
Wheat/unfertilised
Legume/Incorporated
N fertilised wheat = 11.14 - 0.0094x, r=0.44*
Unfertilised wheat = 11.34 - 0.0101x, r=0.46*
Legume/grain harvested = 10.03 - 0.16x, r=0.58**
Legume/grain incorporated = 9.99 - 0.0132x, r=0.42*
AOV: Total regression = *; Slopes = ns; Intercepts = *
Plant density (plants/m)2
Time (days after sowing)

Figure 1

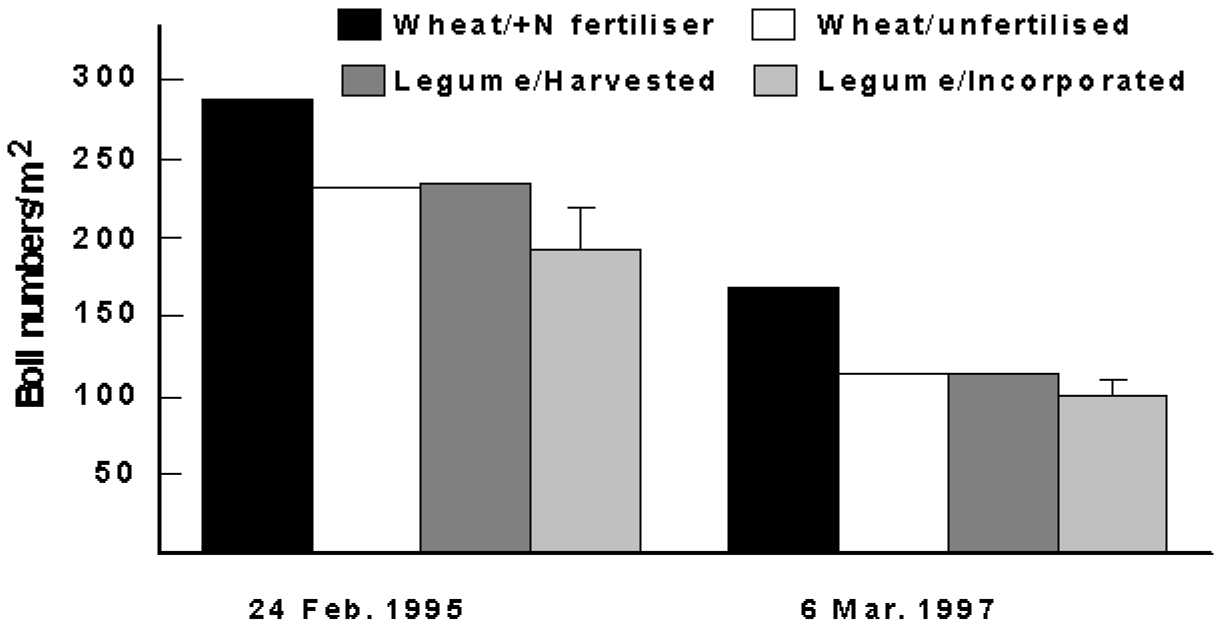

Figure 2

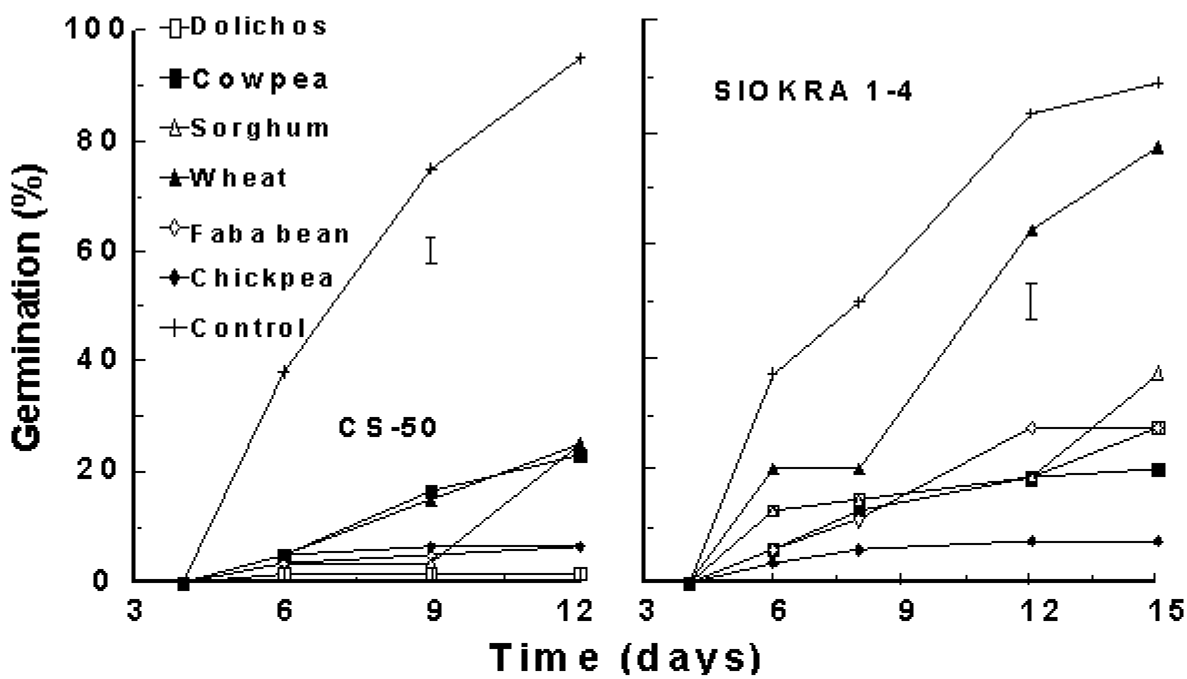

Figure 3

Conclusions

Compared with cereals, seed of leguminous rotation crops, particularly winter legumes, reduced emergence, growth and lint yield, and resulted in poor fibre quality in cotton. Growth reductions were also present when rotation crop stubble was incorporated, but not when it was applied as a surface mulch.

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