THE EFFECT OF SOIL AMMONIUM CONCENTRATION AND OSMOTIC PRESSURE ON SEEDLING EMERGENCE

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INTRODUCTION

It has been established that both the ammonia toxicity (1, 2, 4, 8) and osmotic pressure (3, 5, 9) exerted by a fertiliser compound can affect the germination of seeds and crop establishment. It is not possible to distinguish the absolute effect of ammonia toxicity from the osmotic effect because the ammonium ion from which the ammonia is generated in the soil solution also creates an osmotic pressure. In compound fertilisers containing ammonium, the effects of ammonia toxicity and osmotic pressure combine to affect germination and establishment. This experiment was designed to separate the ammonia (toxicity and inherent osmotic pressure) and osmotic pressure effects for various species, and to discover whether ammonia toxicity and osmotic pressure are additive in their effects on plant emergence.

MATERIALS AND METHODS

The experiment was conducted in a controlled climate cabinet at a temperature (15 ? 2^{o}C) that was favourable to the germination of the species under test. The humidity was kept at 85% and the soil moisture held at field capacity (v/v) with deionised water added by weight, to ensure that the osmotic pressure in the pots remained relatively constant for the duration of the test.

Seeds were sown into 200 mm diameter black plastic pots that were lined with a water tight plastic bag to prevent water loss through drainage. Each pot was first filled with 2 kg of air dry Blenheim black earth (Ug 5.15, Ug 5.16) (6). One kilogram of the same soil was added to the top of the pot after being mixed with the appropriate amount of ammonia contained in 100 mL of water. The seeds were sown approximately 1 cm deep and the soil was drenched with 1100 mL of water containing the predetermined concentration of mannitol to produce the target osmotic pressure.

The treatments consisted of three rates of ammonium (0, 500 and 1500 mg/kg) and three osmotic pressure's (0, -0.6 and -1.2 MPa)

The experiment was laid out in a randomised complete block design with a factorial combination of treatments. Each treatment was duplicated. The five seeds each of canola, chickpeas and wheat were sown in each pot and emergence was recorded every two days until plant number was stable for the majority of treatments.

RESULTS AND DISCUSSION

Final plant establishment

The final establishment figures were taken 22 days after sowing (22 DAS), 16 days after first plants emerged, and when the established plant counts were constant across the majority of treatments.

Chickpeas were significantly more tolerant of the combined effect of increased ammonium concentration and osmotic pressure than wheat and canola. Increasing the soil ammonium concentration to 500 mg/kg did not significantly (P=0.05) affect establishment, but at 1500 mg/ kg the reduction in establishment was highly significant. Osmotic pressures below -1.2 MPa did not affect establishment.

Canola was found to be significantly (P=0.05) more sensitive to increasing osmotic pressure than chickpeas or wheat in the absence of high ammonium concentrations. At the lowest osmotic pressure, emergence of canola was 90 % (4.5 plants emerged from 5 seeds sown), whereas at the highest osmotic pressure canola failed to emerge (Table 1).

Table 1. Final emergence counts for five canola, chickpea and wheat seeds at three rates of ammonium and three levels of osmotic pressure.

	Species									
	Canola			Chickpea			Wheat			
Osmotic Pressure (MPa)	Ammonium Concentration (mg/kg)									
	0	500	1500	0	500	1500	0	500	1500	Means
	(number/pot)									
0	4.5	1	0	4.5	5	2.5	4.5	1.5	0	2.6
-0.6	2.5	4	0	4	3.5	1.5	3.5	1.5	0	2.7
-1.2	0	1.5	0	1.5	4	1	2	1.5	0	1.3
Species Means		1.5			3.1			1.6		
Ammonium Conc. Means				3	2.6			0.6		

Effect	l.s.d. 5%	Significance
species (s)	0.85	**
ammonium concentration (a)	0.85	**
osmotic pressure (p)	0.85	**
s x a	1.48	ns
s x p	1.48	ns
a x p	1.48	*

a x s x p	2.09	ns

In the absence of either high ammonium level or high osmotic pressure in the soil, the final establishment of all species was at least 90% .

At low osmotic pressure, chickpeas were found to be more tolerant of higher ammonium concentration than wheat or canola. The trend for greater ammonium tolerance in chickpeas was evident at higher osmotic pressures but the difference was not as significant.

Rate of emergence

The rate of emergence was assessed as the time taken for each species in each treatment to reach maximum establishment. If for a treatment all seeds failed to emerge, the time taken for emergence was assumed the maximum, 22 days.

Treatments that included high osmotic pressure and high ammonium concentration together, resulted in emergence that parallelled the most extreme of either the osmotic or ammonium response . This confirms the need for caution with fertiliser products such as urea, having both a high *ammonia potential* and a high osmotic pressure (7).

Canola and wheat showed a rapid increase in the time to maximum emergence with increasing ammonium concentration at both 0 MPa and - 0.6 MPa osmotic pressures. Chickpea showed a similar increasing trend at the highest concentrations of ammonium, 1500 mg/kg (Table 2).

Table 2. Effect of three ammonium concentrations and three levels of osmotic pressure on the time to emerge for canola, chickpeas and wheat.

	Species									
	Canola			Chickpea			Wheat			
Osmotic Pressure (MPa)	Ammonium Concentration (mg/kg)									
	0	500	1500	0	500	1500	0	500	1500	Os. P. Means
	(days)									
0	8.5	18.5	22	6.5	6	12	10	13.5	22	13.2
-0.6	14.5	13.5	22	10.5	9.5	15.5	8.5	15	22	14.6
-1.2	22	18.5	22	22	19	20.5	19	12	22	19.7
Species Means	17.9			13.5			16.0			

Ammonium Means	13.5	13.9	20.0

Effect	l.s.d. 5%	Significance
species (s)	2.46	**
ammonium concentration (a)	2.46	**
osmotic pressure (p)	2.46	**
s x a	5.22	ns
s x p	5.22	ns
a x p	5.22	*
a x s x p	7.4	ns

The increase in time to emerge is rarely taken into account when assessing the risk of applying fertiliser at sowing or when assessing the cause of poor crop establishment. Increased time to emerge can have significant effects on crop performance through exposure of the vulnerable shoots and roots to insect and disease attack, and suboptimal growing conditions.

Increasing the osmotic pressure to -0.6 MPa in the absence of ammonium did not significantly change the time to maximum emergence in any of the species tested. By increasing the osmotic pressure from -0.6 MPa to -1.2 MPa, the maximum emergence time increased significantly in each species.

CONCLUSIONS

It was concluded that the species tolerance to the combined effect of ammonium concentration and osmotic pressure when emergence had plateaued, was in the order chickpea > wheat = canola. It could be argued that when relating these results to likely fertiliser response, the type of fertiliser (relative levels of osmotic pressure or osmotic pressure and ammonium concentration), would more correctly describe the tolerance response of the species. Canola and wheat appeared to be more sensitive to ammonium concentration than chickpeas, whereas in the absence of high concentrations of ammonium, all species showed similar responses to increasing osmotic pressure.

The lack of additive or interactive response may have resulted from the limited number of treatment levels used in the experiment.

The rate of emergence of seed after sowing can be a significant factor in the performance of crops. Slow emergence can expose germinating seed to greater risk of disease, insect attack and moisture stress. The results of this study clearly show that increasing osmotic pressure alone can significantly increase emergence time and that the effect is species dependent across the range of species tested.

Based on the results of this experiment, it appears that the response of germinating seeds to fertiliser is a simple relationship that is dependent on the concentration of ammonium or the osmotic pressure and the species involved. The germination response appears to be related to the component (osmotic pressure or ammonium concentration) and level of the component most critical for the species involved. It is therefore erroneous to generalise about the establishment performance of a species or the effect of different types fertiliser, based on a single parameter within the fertiliser eg. osmotic pressure, nitrogen or ammonium content .

Generalisations inherent in current *safe rates of nitrogen with the seed* , as a measurement of risk and the conservatism of the recommendations, have lead to complacency, with fertiliser placed with the seed at sowing. Many farmers currently exceed the *safe* rates recommended, as they have found them conservative. However, significant potential exists for crop establishment failure or significantly slowed establishment as a result of a failure to take into account the interaction of the activity of the fertiliser type (ammonia and osmotic pressure) and changes in soil moisture at sowing from year to year and crop species.

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