Changes in protein and oil composition in high-yield soybean production systems

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Introduction:

Current marketing of soybean [(*Glycine Max* (L.) Merr.] is based on yield, not seed quality. Except for specialty markets, producers pay little attention to the quality (protein and oil) composition of the seed. Quality is becoming a major consideration, especially for the export and animal feed markets (protein focused) and the emerging bio-fuel industry (oil focused). An overall goal is to attain both greater yield along with greater seed protein and oil concentrations. Achieving both of these goals has been difficult as a negative correlation exist among yield and protein concentration, however, there is a positive correlation among yield and oil concentration (Wilson, 2004). Because the major objective for soybean producers is to increase yield, agronomic practices that are implemented to increase yield, may come at a cost to seed quality, specifically seed protein. These agronomic practices may however maximize total protein and oil output per hectare.

Materials and Methods:

Studies were established at three locations in Iowa during 2004, 2005, and 2006. At each location multiple trials were conducted to determine the influence of planting date, row spacing, seeding rate, and cultivar selection on protein and oil concentration and total protein and oil production per hectare (ha^{-1}). Locations included two high-yield locations, De Witt and Whiting, and the low-yield location Nevada. All locations were infested with soybean cyst nematode (*Heterodera Glycines*, Ichinohe; SCN)

1) Planting date x seeding rate

- Four planting date: late April, early May, late May, and early June
- Four seeding rates: 185 000, 308 900, 432 400, 556 000 seeds ha^{-1}
- Cultivar: AG2801

2) Planting date x cultivar

- Four planting dates: late April, early May, late May, and early June
- Six cultivars: five SCN-resistant cultivars (E2620RX, L2811RX, P91M90, S-3012-4, SOI2858NRR), and an SCN-susceptible cultivar NK S32-G5,

3) Row spacing x seeding rate

- Two row spacings: 38-cm and 76-cm
- Four seeding rates: 185 000, 308 900, 432 400, 556 000 seeds ha^{-1}
- Cultivar: AG2801

4) Cultivar

- Twenty-three cultivars: grouped as old SCN-susceptible cultivars (6), new SCN-resistant cultivars (11), and SCN-susceptible cultivars (6)

Plots were harvested with an Almaco small-plot combine and yield was adjusted to 130 g kg^{-1} moisture. Seed samples were collected from each plot at harvest and protein and oil concentrations were determined using near-infrared spectroscopy at the Iowa State University grain quality laboratory. Total protein and oil output ha^{-1} was calculated as g kg^{-1} (protein or oil) x kg ha^{-1} (yield). Data were analyzed in a combined analysis treating years and replication as random effects. Due to strong location by treatment interactions separate analyses were conducted for each location. Proc Corr was used to determine relationships between yield, protein concentration, and oil concentration using individual plot data.

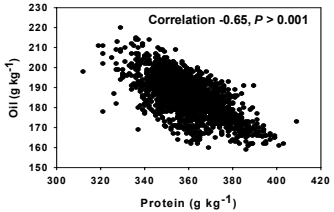

Fig. 1. Seed protein and oil concentration values for different cultivars, row spacings, planting dates, and seeding rates, n=1851

Protein, oil, and yield relationships: Fig. 1

- A strong, negative relationship existed among protein and oil concentration. This response matches with previous observations
- No significant negative correlation (-0.03, P = 0.28) was detected among protein and yield which is unique
- There was a positive correlation (0.14, P > 0.0001) among oil and yield
- These relationships emphasizes the difficulty of increasing both protein and oil at the same time. However, there does appear to be the potential of increasing yield without sacrificing seed quality traits

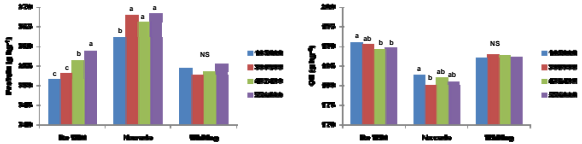

Fig. 2. Protein and oil concentration for four seeding rates, averaged over two row spacing treatments at three locations, 2004-2006. Bars followed by the same letter, not significantly different at P ≤ 0.05

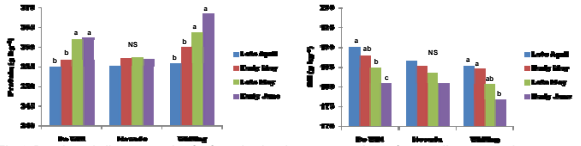

Fig. 3. Protein and oil concentration for four planting dates, averaged over four seeding rates at three locations, 2004-2006. Bars followed by the same letter, not significantly different at P ≤ 0.05

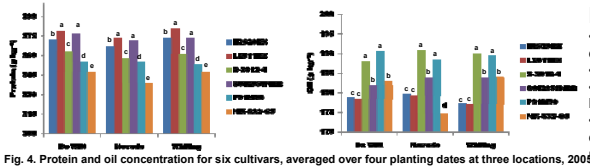

Fig. 4. Protein and oil concentration for six cultivars, averaged over four planting dates at three locations, 2005 to 2006. Bars followed by the same letter, not significantly different at P ≤ 0.05

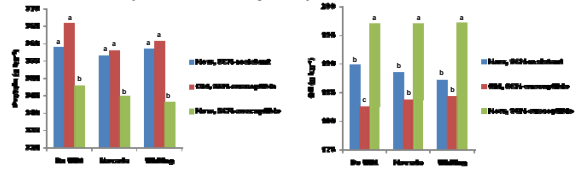

Fig. 5. Protein and oil concentration for three cultivar classes three locations, 2005 to 2006. Bars followed by the same letter, not significantly different at P ≤ 0.05

Row spacing x seeding rate: Fig. 2

- Row spacing did not influence protein or oil concentration
- A seeding rate of 185 000 seeds ha^{-1} produced the lowest protein concentration compared with greater seeding rates at two of the three locations
- Oil concentration responses to seeding rates were small and inconsistent and did not influence oil at Whiting
- Seed from high-yield locations tend to have greater oil but lower protein
- Total protein and oil production ha^{-1} were not influenced by seeding rate due to small yield changes between seeding rates

Planting date x seeding rate: Fig. 3

- Early planting had a consistent, negative effect on protein concentration and a positive effect on oil concentration at Whiting and at De Witt
- Seeding rate responses were similar to the row spacing x seeding rate study and are not presented
- Late April and early May planting produced the greatest yields and also maximized the total protein and oil output ha^{-1}

Planting date x cultivar: Fig. 4

- Substantial protein and oil concentration variability existed among the six cultivars tested but most cultivars responded similarly across locations
- L2811RX and SOI2858NRR achieved both high yield and high protein
- The SCN-susceptible cultivar, NK S32-G5 stood out with significantly lower oil concentration at Nevada and lower protein at all locations
- Total protein and oil production ha^{-1} were maximized using SCN resistant cultivars regardless of location or seed concentration because they produced the greatest yield

Cultivar: Fig. 5

- New, SCN-susceptible cultivars produced the lowest protein concentrations and the highest oil concentrations
- Surprisingly, new, SCN-resistant and old SCN-susceptible cultivars had similar protein and oil concentrations even though final yields were significantly greater for new, SCN-resistant cultivars
- Total protein and oil production ha^{-1} was maximized using new, SCN-resistant cultivars due to greater yield for these cultivars in SCN-infested locations

Summary:

Cultivar selection is the primary method for changing protein and oil seed composition. Agronomic practices, such as time of planting and seeding rate can modify seed quality slightly, but overall, these practices exert more control over total protein and oil output ha^{-1} because of changes in yield.

Acknowledgements:

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References:

Wilson, R.F. 2007. Seed composition. In H.R. Boerma and J.E. Specht (ed.) Soybeans: Improvement, Production, and Uses. 3rd ed. ASA, CSSA, and SSSA, Madison, WI.