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Interactions of agrochemicals applied to peanut; part 1: Effects on herbicides

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ABSTRACT

Numerous agrochemicals are applied in peanut production systems. Field and laboratory experiments were conducted in North Carolina to characterize biological and physicochemical interactions when the herbicides clethodim, imazapic, imazethapyr, lactofen, sethoxydim, and 2,4-DB were applied in combination with adjuvants, fungicides, insecticides, and micronutrients. A wide range of interactions was noted when comparing across herbicides, weed species, and agrochemical combinations. There was little consistency across weed species for a herbicide or across herbicides for a weed species when comparing significant main effects and interactions. In most instances, when compared with the standard herbicide treatment and adjuvant applied alone, herbicide efficacy was not affected in the presence of other agrochemicals. Changes in solution pH and formation of precipitates varied according to the herbicide combinations used. Boron, manganese, and 2,4-DB often caused dramatic changes in solution pH.

1. Introduction

Peanut (*Arachis hypogaea* L.) is an important crop in North Carolina and the southeastern United States (Brown, 2012). The relatively poor competitive ability of peanut necessitates season-long weed control to maximize yield (Jordan, 2012b; Wilcut et al., 1995). Monocotyledonous weeds, including annual and perennial grasses and sedges, as well as dicotyledonous weeds are prevalent in peanut in the United States (Webster, 2009; Wilcut et al., 1995). Comprehensive herbicide programs, in combination with appropriate cultural practices, are employed to manage weeds and minimize interference and subsequent yield loss (Wilcut et al., 1995). In addition to adverse effects of weed interference, diseases, insects, and nematodes can also be deleterious to yield (Brandenburg, 2012; Shew, 2012). Mechanized production systems utilize a wide range of agrochemicals to manage peanut growth and development and minimize the impact of pests on peanut yield and quality (Lynch and Mack, 1995; Sherwood et al., 1995; Wilcut et al., 1995).

Pyrethroid insecticides are often applied to peanut to control corn earworm (*Helicoverpa zea* Boddie), fall armyworm (*Spodoptera frugiperda* J.E. Smith), and potato leaf hopper (*Empoasca fabae* Harris) (Brandenburg, 2012). Fungicides are applied routinely to peanut to control foliar diseases including early leaf spot (caused by *Cercospora arachidicola* Hori), late leaf spot (caused by *Cercosporidium personatum* Berk. & Curtis), and web blotch (caused by *Phoma arachidicola* Marasas, Pauer, and Boerema) (Brenneman et al., 1994; Culbreath et al., 2008; Shew, 2012). Fungicides are also applied to control soil-borne diseases such as stem rot (caused by *Sclerotium rolfsii* Sacc.) and Sclerotinia blight (caused by *Sclerotinia minor* Jagger) (Brenneman et al., 1994; Culbreath et al., 2008; Smith et al., 1992). Although variation is noted among geographical regions, years, and environmental conditions, during a typical growing season fungicides are applied either singly or in combination beginning approximately 45 days after peanut emergence, and continuing throughout the growing season up to several weeks prior to digging and vine inversion (Sherwood et al., 1995; Shew, 2012; Smith and Littrell, 1980).

The micronutrients boron and manganese are applied routinely to optimize peanut growth and development and, in the case of boron, to ensure proper kernel development (Gascho and Davis, 1995; Harris and Brolman, 1966; Jordan, 2012a; Powell et al., 1996). Single and, in some cases, multiple applications of boron-containing foliar solutions are applied 45–70 days after peanut emergence (Gascho and Davis, 1995). Manganese deficiency occurs frequently in peanut fields because of liming and establishment of a soil pH above 6.0. Correcting manganese deficiency is achieved by foliar applications when visible symptoms become

Abbreviation: h, hours.
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apparent, although some growers apply manganese irrespective of plant symptomology (Jordan, 2012a; Powell et al., 1996).

A diversity of pesticide active ingredients is available for use in peanut production systems (Brandenburg, 2012; Jordan, 2012b; Shew, 2012). Currently, 19 herbicide active ingredients, 16 insecticide active ingredients, and 20 fungicide active ingredients representing the major modes of action can be applied during the peanut growing season. Three fumigants, two micronutrients, and one plant growth regulator can be used in peanut. The biotic and abiotic stresses mentioned previously often occur simultaneously during the peanut growing season, and timing of application for many agrochemicals overlap. Therefore, there is desire to apply herbicides, fungicides, insecticides, and foliar micronutrients simultaneously in peanut production systems. This approach is preferable because of convenience, savings in time, reduced application costs, and lower labor costs. In spite of the above mentioned benefits, incompatibility can be associated with these mixtures. Co-applying pesticides can negatively influence agrochemical efficacy and increase crop phytotoxicity (Green, 1989; Hatzios and Penner, 1985). Defining interactions of agrochemicals is important when considering applying agrochemicals simultaneously (Barrett, 1993; Green, 1989; Hatzios and Penner, 1985; Nash, 1981; Wehtje et al., 1992).

Incompatibility can occur through physicochemical interactions in the spray tank, while biological incompatibility occurs on plant surfaces or by affecting physiological processes associated with differential absorption, translocation, and metabolism (Cohen, 1984; Maestri and Currier, 1958; Putnam and Penner, 1974; Smith, 1983). Lack of physicochemical compatibility of different agrochemicals in the spray tank may lead to the formation of precipitates or change in spray solution pH which may adversely affect delivery of pesticide to the target site and consequently decrease pest control (Houghton, 1982). Water pH affects the stability and efficacy of weak acid herbicides such as clethodim, sethoxydim, glyphosate, 2,4-D, and 2,4,5-T (Baur et al., 1974; Blackman and Robertson-Cuninghame, 1953; Buhler and Burnside, 1983; Nalewaja et al., 1994). These herbicides readily ionize, if the pH of the spray solution increases above the pKa value of the herbicide (Bukovac et al., 1971; McMullan, 1996). Hydrolysis can reduce stability of pesticide active ingredients in spray solutions (Das et al., 2004). Previous researches reported that sulfonylurea herbicides become more stable at alkaline pH (Matocha and Senseman, 2007; Matocha et al., 2006). However, literature showing influence of spray solution pH on imidazolinone and diphenyl ether herbicides is limited.

Efficacy of one ingredient can be affected by the biological activity of the other (Johanson and Kaldon, 1972). To overcome these adverse interactions, more efficacious formulations or spray adjuvants can be used (Jordan et al., 1996; Stock and Briggs, 2000; Strahan et al., 2000). Adjuvants can increase herbicide efficacy by improving the physical characteristics of the carrier while other adjuvants improve efficacy by enhancing agrochemical movement through waxy or dry cuticles of plants or by reducing surface tension of spray solutions or by hydrating the leaf surface (Hazen, 2000).

Interactions of agrochemicals can increase crop phytotoxicity and decrease pest control (Byrd and York, 1988; Franzen et al., 2003; Jordan et al., 2003; Pankey et al., 2004). Research has been conducted to define interactions between herbicides (Burke et al., 2004; Culpepper et al., 1999; Flint and Barrett, 1989; Wehtje et al., 1992), herbicides and fungicides (Jordan et al., 2003; Lancaster et al., 2005a, 2005c, 2008), herbicides and insecticides (Lancaster et al., 2005b), and herbicides and micronutrients (Jordan et al., 2006, in press; Lancaster et al., 2005b; Nalewaja and Matysiak, 1993). Although some interactions described in the literature have been defined for some three-way mixtures, reports on the interactions of four- or five-way components are limited.

Defining interactions among agrochemicals is important in assisting growers and their advisors as they make decisions on co-application of these products. Therefore, the objectives of this research were to define interactions when herbicides are applied alone or in combination with adjuvants, fungicides, insecticides, and micronutrients with respect to weed control and to determine changes in solution characteristics with these combinations.

2. Materials and methods

2.1. Interactions of herbicides with other agrochemicals in the field

Research was conducted in North Carolina during 2008 and 2009 at the Central Crops Research Station located near Clayton, the Peanut Belt Research Station located near Lewiston-Woodville, and the Upper Coastal Plain Research Station located near Rocky Mount. Soils were a Johns sandy loam soil (fine-loamy over sandy, siliceous, semiactive, thermic Aquic Hapludults) at Clayton, a Goldsboro fine sandy loam soil (fine-loamy, siliceous, subactive, thermic Aquic Paleudults) at Rocky Mount, and a Norfolk sandy loam (fine-loamy, kaolinitic, thermic Typic Kandiudults) at Lewiston-Woodville. Experiments were conducted in peanut or in non-crop areas with uniform weed populations. Plot size was 2.4 by 4.6 m.

In separate experiments, efficacy of clethodim (Select Max Herbicide, Valent U.S.A. Corporation, Walnut Creek, CA) (200 g ai/ha), imazapic (Cadre Herbicide®, ammonium salt of imazapic, BASF Corporation, Research Triangle Park, NC) (70 g ai/ha), imazethapyr (Pursuit Herbicide®, ammonium salt of imazethapyr, BASF Corporation, Research Triangle Park, NC) (70 g ai/ha), lactofen (Cobra Herbicide®, Valent USA, Walnut Creek, CA) (220 g ai/ha), sethoxydim (Poast product label, BASF Corporation, Research Triangle Park, NC) (130 g ai/ha), and 2,4-DB (Butyrac 200 Herbicide®, dimethylamine salt, Albaugh Inc., Ankeny, IA) (280 g ae/ha) was determined when applied alone or with fungicides, insecticides, micronutrients, and adjuvants. The treatment structure consisted of the following: three levels of fungicide, including no fungicide, chlorothalonil (Bravo Weather Stik®, Syngenta Crop Protection, Inc., Greensboro, NC) (840 g ai/ha) plus tebuconazole (Folicur® 3.6 F Foliar Fungicide, Bayer Cropscience LP, Research Triangle Park, NC) (220 g ai/ha), or pyraclostrobin (Headline fungicide, BASF Corporation, Research Triangle Park, NC) (170 g ai/ha); two levels of insecticide, including no insecticide or lambda-cyhalothrin (Karate Z insecticide, Syngenta Crop Protection, Inc., Greensboro, NC) (17 g ai/ha); and three levels of micronutrient, including no micronutrient, boron (Nutrisol 10% B, Coastal Agrobusiness, Inc., Greenville, NC) (2.34 L/ha), or manganese (Nutrisol 8% Mn, Coastal Agrobusiness, Inc., Greenville, NC) (2.34 L/ha). Two levels of adjuvant were included in each experiment but varied by herbicide. Crop oil concentrate (Agri-Dex® nonionic spray adjuvant, Helena Chemical Company, Collierville, TN) or conditioning agent (CLASS® ACT®NG, water conditioning agent and nonionic surfactant blend, Winfield Solutions, St. Paul, MN) were applied with clethodim and sethoxydim. Nonionic surfactant [Induce®, blend of alkylarylpolyoxylkane ether, free fatty acids, and isopropyl (90%), and water and formulation acids (10%), Helena Chemical Corporation, Collierville, TN] or conditioning agent were applied with imazapic, imazethapyr, and lactofen. Efficacy of 2,4-DB combinations was compared with no adjuvant or conditioning agent. Conditioning agent and crop oil concentrate were applied at 1.0% (v/v). Nonionic surfactant was applied at 0.25% (v/v). The peanut cultivar Phillips (Isleib et al., 2006) was used in these experiments and peanut was planted during the first two weeks of May during each year.