

To Study the Impact of Glyphosate on Chlorophyll Content of Crops

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ABSTRACT: Glyphosate is the widely used herbicide to control a broad spectrum of plants including annual and perennial grasses, broadleaf weeds, trees and shrubs around the world. When spray applications of the glyphosate contact the crop, great damage can occur and is of great concern to aerial applicators and farmers. In non-glyphosate-resistant crops (non-GR), glyphosate causes a metabolic disturbance and reduction in chlorophyll content. The damage can drastically reduce crop yield and growth for an extended period of time. Chlorophyll content of a leaf is always a good indicator of photosynthesis activity, stress and nutritional state and is of unique significance to precision agriculture. Given that recommended doses of glyphosate are generally higher than needed to control weeds. The most prudent approach to reduce the adverse effects of glyphosate on glyphosate-resistant (GR) crops will be to use this herbicide in as small a dose as almost needed. This paper states the work that is done on different crops at different places to observe the effects of glyphosate on crop leaves. The authors used different spectral indices to measure the chlorophyll content and to distinguish the healthy and injured leaves.

KEYWORDS: Chlorophyll, Glyphosate, Herbicide, Metabolic, Spectral Indices.

I. INTRODUCTION

Glyphosate is highly active even at low doses on sensitive plant species and is a chemical compound which is an active ingredient in some herbicide products. It is a non-selective and systemic herbicide which is absorbed through green stem tissues and plant leaves and highly toxic to sensitive plant species. In the past decade, glyphosate has been widely used for weed management in agricultural fields because of the increased utilization of genetically modified crops that are resistant to glyphosate. When glyphosate is sprayed to GR crops, its drift onto off-target sensitive crops such as non-GR crops may cause damage and significant reduction in yield or quality. It is highly active on sensitive plant species even at low doses.

When the glyphosate lands on the off-target plant surfaces such as crop leaves, undesirable damage can occur. In glyphosate applications, main objective is to minimize off-target drift that may cause injury to other crops. However, when drift does occur, it is necessary to detect the onset of the crop injury due to herbicide drift, and be able to determine the relationship between the crop injury and dosage of herbicide. Many times glyphosate causes growth reduction as well as chlorosis and necrosis.

Glyphosate applications are commonly used to kill perennial and undesirable weedy plants in agriculture. Many researches had shown that foliar biochemistry would change as a result of glyphosate application and are always accompanied by reduction of chlorophyll content in a crop.

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II. RELATED WORK

Vegetation monitoring is an important application of remote sensing. Many satellite missions have been launched with the aim of monitoring changes in the vegetation cover over the Earth surface. Detecting herbicide injury to crops using biological responses is difficult, so more convenient and rapid detection methods are required.

Krishna N. Reddy et al. conducted a greenhouse experiment to examine glyphosate effects on growth and chlorophyll content. It was found that in susceptible soybean, a single application of 0.28 kg/ha glyphosate decreased chlorophyll content (49%) as well as shoot and root dry weight (50 and 57%, respectively) at 2 week after treatment. In GR soybean, there were no effects on these parameters by single application up to 1.12 kg/ha, but 2.24 kg/ha reduced shoot and root dry weight by 25 to 30% [1].

Anatoly A. Gitelson et al. investigated the spectral reflectance of maple, chestnut, wild vine and beech leaves in a wide range of pigment content and composition. It was shown that reciprocal reflectance ($R \lambda$) -1 in the spectral range λ from 520 to 550 nm and 695 to 705 nm related to the chlorophyll content present in leaves of all species. Reflectance measurement makes it possible to rapidly and non-destructively evaluate the chlorophyll content in leaves [2].

Krishna N. Reddy et al. conducted a field study during 2000 and 2001 at Stoneville, MS, to determine the effects of glyphosate on weed control, chlorophyll content, growth, nitrogen content, and grain yield in GR soybean. Glyphosate at 0.5 mM reduced chlorophyll content in hypocotyls of non-transgenic soybean grown in liquid culture and glyphosate can decrease plant growth [3].

G. le Maire et al. experimented on fifty-three leaves picked randomly sampled on different deciduous tree species, representing a wide range of chlorophyll contents, and leaf structural features. Their reflectance was measured between 400 and 800 nm and their chlorophyll content was extracted. After calibration on the experimental database, modified Normalized Difference (mND) and modified Simple Ratio (mSR) indices gave the best performances (RMSECV=1.8 Ag/cm² on the experimental database). The reflectance-based indices give good performances than the current commercial non-destructive device SPAD (RMSECV=4.5 Ag/cm²) [4].

Clifford H Koger et al. conducted a greenhouse and field studies to investigate response of two rice varieties, Priscilla and Cocodrie to glyphosate. Noticeable visual injury and height reduction to both varieties was observed as early as 7 and 3 DAT (Days After Treatment) in Cocodrie and Priscilla, respectively. The highest rate of glyphosate reduced yield in Cocodrie by 92% while there was only a 60% yield decrease in Priscilla [5].

Scot Nelson found that when spray applications of the herbicide glyphosate contact the coffee plant, extensive injury can occur. It may also predispose plants to many diseases, such as nutritional deficiencies. Effect of glyphosate on coffee plants can negatively affect plants or persist for many months, up to one year or more on coffee in Hawai'i, depending on the dosage of glyphosate. The negative impacts of glyphosate to coffee plants include arrested growth of plants, nutritional deficiency symptoms (foliar yellowing), and poor coffee bean yields [6].

Chaoyang Wu et al. did a study with four new formed indices (MSR [705,750], MCARI [705,750], TCARI/OSAVI [705,750] and MCARI/OSAVI [705,750]) that were proved to have better linearity with chlorophyll content. Validation study was also done using the ground truth data in the growth duration of winter wheat (chlorophyll content and reflectance data). The results showed that the integrated indices TCARI/OSAVI [705,750] and MCARI/OSAVI [705,750] are most appropriate for chlorophyll estimation [7].

G.S. Johal et al. found that a significant increase in disease associated with the application of the glyphosate herbicide. It includes weakening of plant defences. They believe that the most appropriate method to reduce the effects of glyphosate on crops will be to use this herbicide in a small dose as practically required [8].

Y. Huang et al. found that spray drift sampling can detect early cotton injury (1 Weeks After Treatment), and airborne remote sensing can detect late cotton injury (2 and 3 WAT). The results are useful for deciding the extent of required near-field drift sampling and exhibit that airborne multispectral imaging can be a viable tool for deciding the extent of damage relative to derived concentrations of glyphosate herbicide [9].

Krishna N Reddy et al. found that the corn injury and many other biological responses point to the same conclusion, that is, damage from glyphosate aerial drift is more at the edge of the spray swath and reduces gradually with distance [10].

Wei Ding et al. found that chlorophyll reduction was more (80%) in soybean compared with cotton (43%) at 0 m from the edge of the spray at 1 WAA (Week After Application). The biological response of soybean and cotton crop to

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glyphosate herbicide drift declined with increased distance from the edge of spray swath. These results showed that soybean was more susceptible to glyphosate drift than cotton [11].

Haibo Yao et al. found that vegetation indices could recognize crop injury at 24 h after application (HAT), at which time visual inspection could not distinguish between glyphosate injured and non-treated plants. Four vegetation indices, namely, NDVI, SAVI, TVI, and VNNIR, were found relevant in detecting plant damage. The study showed that hyperspectral imaging of plant canopy reflectance could be an important tool for early detection of soybean crop damage from glyphosate. The modified spectral derivative analysis had a good performance than vegetation indices [12].

Y. Huang et al. found that corn was the most sensitive to the glyphosate induced injury and showed extensive injury at 1 WAT. Soybean was less sensitive to the glyphosate drift than corn and more sensitive than cotton, and soybean injury was clearly observable at 1 WAT and 2 WAT. Crop physical responses (visual injury and plant height) can be directly used to model the injury of cotton caused by the drift of aerially applied glyphosate at 1 and 2 WAT, the injury of corn at 1 WAT, and the injury of soybean at 1 and 2 WAT. In turn, the models can be evaluated by a physiological response such as chlorophyll [13].

Feng Zhao et al. found that glyphosate damage could be detected by NDVI (Normalized Difference Vegetation Index), RVI (Ratio Vegetation Index), SAVI (Soil Adjusted Vegetation Index), and DVI (Difference Vegetation Index) in 48 HAT for soybean and in 72 HAT for cotton [14].

Xiuliang Jin et al. found that the total leaf chlorophyll content (TLCC) provides valuable information about the physiological status of crops. The objectives of this study were to analyse the leaf area index (LAI) and soil factor that influences the estimation of TLCC using the PROSAIL model, which is a combination of the PROSPECT leaf model and the SAIL canopy model [15].

Tarundeep Kaur et al. found that Application of K salt of glyphosate at 1350 to 5400 g/ha recorded the weed control efficiency (WCE) ranging from 96.8-99.8%, and resulted in more seed cotton yield. The performance of succeeding crops of wheat, barley and raya sown after cotton was not affected, resulting no residual toxicity of K-salt of glyphosate application. The glyphosate, when sprayed to the field area not only control weeds and unwanted crops, but may also leave unwanted residues in the soil, which are ecologically harmful [16].

Yanbo Huang et al. found that plant height and chlorophyll (CHL) content declined gradually with increasing dosage of glyphosate, regardless of WAA. The Vis were highly correlated with plant height and yield but inadequately correlated with CHL, regardless of WAA [17].

R. N. Sahoo et al. found that compared to direct field techniques, remote sensing techniques have been shown to be timely, non-destructive and provide spatial estimates for quantifying and monitoring chlorophyll content [18].

L. J. Martinez M et al. decided that the aim of the research was to find the relation between chlorophyll contents and spectral measurements in a maize crop. Spectral measurements were taken and the chlorophyll content of maize crop was extracted in an experiment with different N rates. Examination of variance showed differences in the chlorophyll content and spectral indices and strong correlations between some chlorophyll content and reflectance indices [19].

Facundo Carmona et al. estimated the NAVI with different pairs of bands and a correlation matrix with NAOC index. NAVI is obtained using only two bands on red and near infrared regions of the spectrum. Results showed very good linear correlation coefficients, with values ≥ 0.97 . NAVI allows estimating leaf CHL from satellite data with medium spectral resolution [20].

III. METHODOLOGY

Krishna N. Reddy et al. conducted an experiment in which chlorophyll was extracted with 5 ml dimethyl sulfoxide and chlorophyll concentrations were identified spectrophotometrically [1]. G. le Maire et al. measured the reflectance spectrum between 400 and 800 nm with a spectrophotometer with a 1 nm step. The leaf reflectance model PROSPECT is used in this study [4]. Chaoyang Wu et al. found that an easy method for determining the chlorophyll content of wheat and crop was using the portable Chlorophyll Meter SPAD-502 [7].

Y. Huang et al. found that NDVI can be a good tool to profile the growth gradient downwind from field treatment for evaluation of the effect of aerially applied glyphosate drift on non-GR cotton during the entire growing season following field treatment [9]. Wei Ding et al. determined the chlorophyll content using the youngest fully expanded leaf from three randomly sampled plants at each location at 1, 2, and 3 WAA. Chlorophyll was extracted with 10 mL dimethyl sulfoxide,

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and chlorophyll concentrations were quantified spectrophotometrically [11]. Haibo Yao et al. conducted a study to measure the canopy reflectance of soybean plants using a portable hyperspectral image sensor in a greenhouse [12]. L. J. Martinez M et al. used several spectral vegetation indices to identify the better indices that are related to the chlorophyll content. Analysis of variance (ANOVA procedure) was used to determine the effect of the treatments on the spectral measurements [19]. Facundo Carmona et al. used spectra of different crop plots obtained with the CHRIS (Compact High Resolution Imaging Spectrometer) sensor [20].

IV. RESULT AND DISCUSSION

Krishna N. Reddy et al. found that a single application of glyphosate at rates less than 1.12 kg/ha did not affect chlorophyll content in glyphosate-resistant soybean at 2 and 4 WAT. Application of glyphosate at 2.24 kg/ha reduced chlorophyll content 25% at 2 WAT. However, glyphosate applied at rates above 4.48 kg/ha reduced chlorophyll content in glyphosate resistant soybean to less than 27% of control at 2 WAT [1].

G. le Maire et al. found the mSR-like index $(R780 - R710) / (R780 - R680)$ as best. The other two indices (mNR and mSR) were used over a wide collection of leaves of different species. Contrary to the first index, these two indices have the benefit to agree well with simulated reflectances. The estimated accuracy on leaf chlorophyll content for the experimental data set was about 2 Ag/cm² (and between 5 and 6 Ag/cm² on the basis of the more general simulated database) [4].

Clifford H Kogeret. al. found that injury to rice varieties Cocodrie and Priscilla increased significantly with increasing glyphosate rate. Injury to Cocodrie and Priscilla ranged from 10 to 20% and 45 to 70% at rates of 26 and 420 g ha⁻¹, respectively. Stunting of plant growth and chlorotic discoloration of tissue characterized injury [5].

ChaoyangWu et.al. found that indices that can evaluate chlorophyll content more precisely (better linearity with increasing chlorophyll content of crops) will be the good choice especially for high content of chlorophylls [7].

G.S. Johalet.al. found that more use of glyphosate can significantly increase the severity of various diseases by impacting all four components of the “plant disease diamond” comprised of the plant, abiotic and biotic environments, and pathogen. Reduced growth, impaired defences, impaired uptake and translocation of nutrients and altered physiology of plants by glyphosate can affect susceptibility to various diseases [8]. Y. Huang et al. found that less deposited chemical produced less crop damage as detected by remote sensing downwind [9].

Krishna N Reddy et al. found that Corn was unaffected in the upwind direction from the edge of the spray swath, but injury was observed downwind of the spray swath. Injury symptoms included chlorosis of the youngest leaves, necrosis, stunted growth and plant death. At 1 WAA, chlorophyll reduction decreased from 78% at 6 m to 22% at 15.8 m, with chlorophyll content unaffected beyond 25.6 m [10].

Wei Ding et al. determined that glyphosate effects on soybean and cotton injury (chlorosis, necrosis, stunted growth, and plant death) were apparent within 1 WAA. Regardless of evaluation timing and crop, plant damage at 0 m was at least 75% but declined to less than 23% at 35.4 m downwind [11].

Haibo Yao et al. concluded that hyperspectral imaging of plant canopy reflectance could be an important tool for early detection of soybean crop damage due to glyphosate application, and that the modified spectral derivative analysis proved to be good at detecting this than the vegetation indices [12]. Y. Huang et al. found that impact of glyphosate drift on cotton, corn, and soybean was observable but decreased with time in three weeks due to plant death (especially in corn and soybean), and cotton showed regrowth [13].

TarundeepKauretal. observed no significant injury on Bt cotton in any herbicide treatment, which indicated that the herbicide was safe for Bt cotton [16]. L. J. Martinez M et al. found that the nitrogen rates applied had a significant effect on chlorophyll content of maize and on spectral responses [19]. Facundo Carmona et al. found that the relationship between NAOC and NAVI was proved, considering different pairs of bands, which justifies the simplification, proposed for assessing leaf CHL using only two spectral bands [20].

V. CONCLUSION

Glyphosate application for weed control can drift onto an off target area, causing unwanted damage to crops. Chlorophyll content is a good indicator of plant health. The objective of this study is to determine the relationship between glyphosate application on weeds and chlorophyll content of crops surrounded by weeds. It is concluded that this study is useful for

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determining the effects of glyphosate on chlorophyll content of crops and can be used to identify the glyphosate injured leaves. Thus, early detection of crop injury from off-target drift of glyphosate is essential in crop production.

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