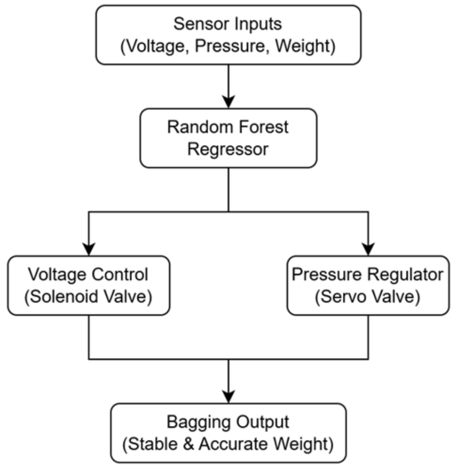
Supplementary for IJTECH



Supplementary 1 Conceptual framework of the proposed machine learning-based bagging control system.

Supplementary 2 Summary of Sensors and Hardware Components

Component	Model	Manufacturer	Range	Resolution
Load Cell	Strain Gauge	Vishay	20 kg	0.05%
Pressure Transmitter	PSE563	SMC Corporation	0–100 Bar	<0.50% FS
Motorized Potentiometer	PRM16 Series	Bourns Inc.	1K ohms to 1 Megohm	±20%
ESP32-S3 Controller	ESP32-S3	Espressif Systems	3.3V	Dual-core 1500 MHz, 448 KB ROM, 520 KB SRAM
INA226 Sensor	INA226	Texas Instruments	0–36 V, 0–819 mA	12-bit ADC

Supplementary 3 Comparison of MAPE values based on the number of trees

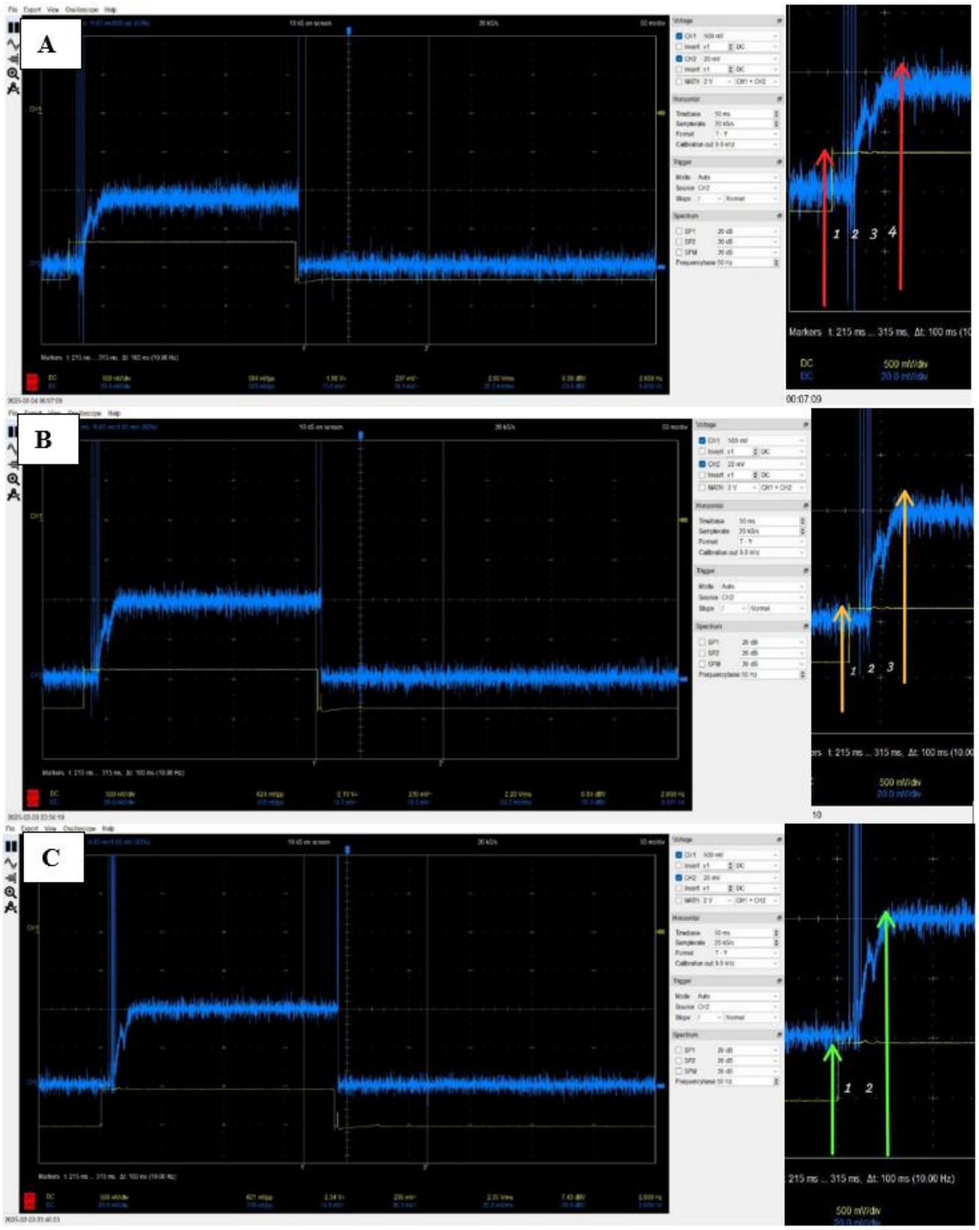
Number of Trees	MAPE (%)
5	0,12
9	0,10
19	0,11
29	0,13
39	0,15
50	0,09
100	0,093
150	**0,085**
200	0,089

Supplementary 4 Comparison of RMSE values based on the number of trees

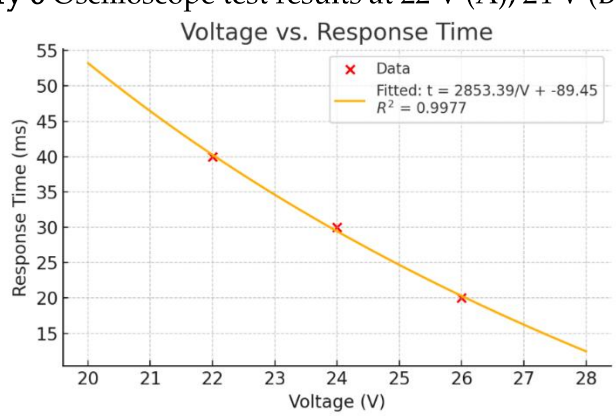
Number of Trees	RMSE
5	0,079
10	0,076
20	0,073
30	0,071
40	0,065
50	0,059
100	0,062
150	**0,043**
200	0,053

Supplementary 5 PID, MPC, and the proposed RFR-based control

Aspect	PID Controller	MPC	Proposed (RFR)
Control Type	Reactive control using error correction; simple but lacks prediction (Åström and Murray, 2008).	Predictive control using system model; effective but complex (Rawlings et al., 2017).	Predictive, data-driven control using historical data (Nieto et al., 2024b).
Adaptability	Requires manual tuning when conditions change (Kaewluan et al., 2025).	Adaptable if model is updated regularly (Kang-Xing et al., 2025).	Automatically adapts through retraining with new data (Oshiro et al., 2012).
Model Dependency	No system model needed (Zermani et al., 2025).	Needs accurate process model (Rawlings et al., 2017).	No physical model required; learns from data (Breiman, 2001).
Nonlinearity Handling	Limited to near-linear systems (Åström and Murray, 2008).	Can handle nonlinear systems with added complexity (Ghiat et al., 2025).	Supports nonlinear, multivariable relationships.
Computational Load	Very low; suitable for simple systems (Kaewluan et al., 2025).	High; solves optimization problems at each step (Ghiat et al., 2025).	Moderate; fast inference after training (Chen and Lv, 2022).
Implementation	Easy to deploy and tune (Kholiq, 2025).	Complex setup with modeling and solver (Ghiat et al., 2025).	Requires dataset and training; easy to integrate after (Breiman, 2001).
Suitability for Bagging	Cannot respond well to multivariable dynamics and process drift (Zermani et al., 2025).	Challenging due to modeling and speed constraints.	Well-suited; supports fast, adaptive multivariable control (Mary M. et al., 2025).



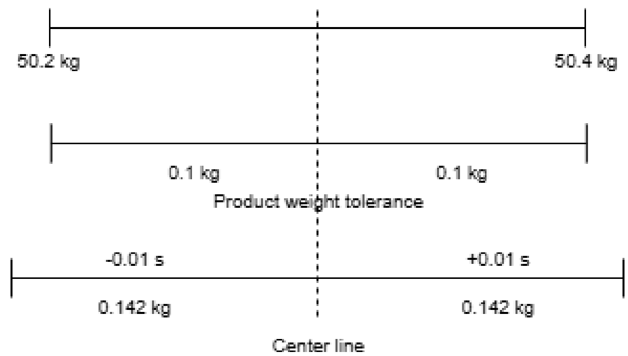
Supplementary 6 Oscilloscope test results at 22 V (A); 24 V (B); 26 V (C)



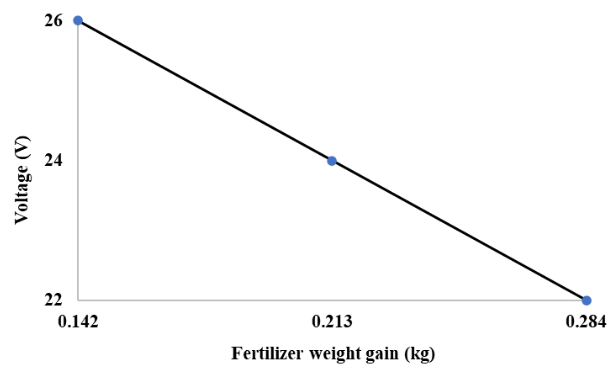
Supplementary 7 Voltage vs. Solenoid Valve Response Time and Fitted Inverse Model

Supplementary 8 The correlation between response time and voltage required by the SOV

Response Time	Voltage
0.2	30
0.3	28
0.4	26
0.5	24
0.6	22
0.7	20



Supplementary 9 Urea fertilizer weight specifications



Supplementary 10 Urea fertilizer weight specifications

Supplementary 11 Comparison of Predicted and Actual Air Pressure Based on PWM Duty Cycle

Duty Cycle (%)	Servo Degree (°)	Predicted Air Pressure (Bar)	Actual Air Pressure (Bar)
10	18	1.0958	1
20	36	2.0944	2
30	54	3.0931	3
40	72	4.0917	4
50	90	5.0903	5
60	108	6.0889	6
70	126	7.0875	7
80	144	8.0862	8
90	162	9.0848	9
100	180	10.0834	10